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H. J. Muller on Life Forms To Be Expected Elsewhere Than On Earth

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Life Forms to Be Expected Elsewhere Than on Earth*

H. J. MULLER, *Indiana University, Bloomington*

In this age of beginning space flight, many of our more alert students are avidly reading the literature that is commonly miscalled science fiction, and this they cannot be blamed for. As yet, it has provided them with almost their only available source of ideas concerning the possibilities of life on other worlds. Yet there is much in existing biology that bears on the interesting questions here involved. Let us review some of these matters, in order to lay a basis for giving our students better guidance in this legitimate quest of theirs than is currently to be found in the fabrications of romancers. We shall soon find that such a study leads through some of the livest problems of modern biology.

We may first recall an incident that happened soon after the great Polish astronomer Copernicus published his evidence, in the late 1500's, that the sun is far greater than the earth, that the earth and planets move around the sun, not the sun around the earth, and that stars are other suns ever so much farther away. This was in reality a view that had been originated by the Greek Aristarchus 2,000 years before Copernicus but that had been ridiculed as contrary to the religious teachings of the time and had been almost forgotten. In fact, Copernicus's great book was not published until just after his death, since he was afraid to have it appear while he was alive.

Shortly after it was published the Italian clergyman Giordano Bruno, convinced by this discovery, pointed out that there are probably many other worlds than ours, other planets belonging to other stars than our own sun, on which living things exist, some of them intelligent beings. Chiefly because he refused to take back this view, Giordano Bruno was in the year 1600 burned at the stake by the Holy Roman Inquisition. It is reported that as he was led to the stake he said: "Perhaps you who pronounce this sentence against me do so with greater fear than I who hear it." If he said this, he was in reality accusing his accusers of attempting to suppress the search for truth because of their suspicion that they might themselves be shown to be wrong.

1. *Planetary Origins*

At any rate, the idea would not down, and it grew very prominent after the German philosopher Kant and, independently, the French mathematician Laplace around 1800 proposed that the whole solar system of our sun and planets had originated from a great cloud of gas by its gradually falling together —condensing—as a result of the pull of gravitation on the particles. If this had happened in the case of our sun, it was realized, it might have happened similarly in the formation of millions of other stars also. So there might well be countless planets, and on many of these life might exist. However, during the early years of the present century, astronomers became very skeptical of this view of the origin of planets because of difficulties they encountered in explaining why part of the gas, in condensing, had got left so far out, as planets, supplied with such a high energy of rotation around the sun and around their own axis.

It was then proposed, instead, that the planets had originated by the sideswiping of one star by another one. It was rightly calculated, however, when the great distances between the stars and their speeds with respect to one another were reckoned with, that such an event would happen so very rarely as to allow hardly any stars to have acquired planets. But instead of concluding that this result made their hypothesis highly unlikely as the explanation of how our own sun's planets had arisen, they decided that our sun must be nearly unique in having planets. If this were true, life could hardly exist in our galaxy except on planets of a very few stars, and there was practically no hope left for any intelligent life to exist in our galaxy except on our earth.

*Based on an address delivered by Nobel Laureate Muller at the NABT luncheon held at the Sherman Hotel, Chicago, December 28, 1959, in connection with the Annual Meeting of the AAAS, and in modified form at Taylor University, Upland, Indiana, on March 14, 1961 in its Science Emphasis Week.

Dr. Muller (left) is shown here with Past President Paul Klinge at the NABT Luncheon, December 1959.

However, during recent years new findings bearing on this matter have come to light and new calculations have been carried out on the way in which matter scattered in space must aggregate. All this new evidence indicates that the view proposed by Kant and by Laplace was correct in its essentials after all. Mechanisms have been worked out by which, in the condensation of gas and dust to form stars, not all of the material accumulates at one center. As Kuiper has pointed out, the evidence from double and multiple stars shows that, as expected, the gas more often condenses into two or more main centers that revolve about each other, and that there is a random distribution of sizes for these bodies, one of them frequently being much bigger than the other or others. In the limiting situation, that can be calculated to occur in at least 5 percent of cases, the great bulk of the material settles into one central star, or sun, while the rest is so small in amount that the other body or bodies would fall under the definition of planets and would not naturally support thermonuclear reactions of their own. Such planets could range in bulk from bodies much larger than Jupiter to those of sizes like the planets in our own solar system.

Although even the largest could not be seen telescopically by present methods, because of the great remoteness of other stars from us, nevertheless this conclusion has been backed by observations showing small perturbations in the motion of some stars, which prove that smaller dark bodies, much larger, however, than Jupiter, must accompany them. Bodies still smaller than this could not cause perturbations large enough to be detected by us. Nevertheless, all these points hang together and lead astronomers back again to the view that outside our own solar system there exists an enormous number of stars possessing families of planets.

2. Conditions for the Formation of Organic Compounds

But before a planet can support life, it must be supplied with the right chemical elements. It has been concluded that the earliest stars and their planets must have consisted of so little else than the very lightest elements, hydrogen and helium, as not to have allowed the formation of organic substances in sufficient amount for the maintenance of life. Only long afterwards, as these stars in their death throes formed somewhat heavier elements deep in their interiors, and then spewed their contents out into space, was it possible for this material to recondense. In this way it gave rise to later generations, as they are called, of stars and their planets. These were supplied, from their beginning, with more of the moderately heavy elements than the first stars had. Included here were not only carbon, oxygen, and nitrogen, but also, after more cycles, such elements as phosphorus, magnesium, and iron, all of which are necessary for life as we know it. Our own sun, it is thought, is a star of a third or even later generation, and any earlier generation than it would probably not have been provided with enough of these strategic heavier materials for the needs of active living.

Besides having suitable elements, a planet that supports life as we know it must have its temperature within a certain moderate range. Water constitutes the medium in the cell in which the chemical reactions that characterize life take place. Thus, while the operations of life are going on, the temperature must be above that of ice and below that of steam, and it must never rise high enough to destroy the essential organic compounds. In our own solar system, this condition would not allow life on a planet averaging much farther from the sun than Mars nor much nearer than Venus. The

planet should also rotate on its axis at a fair velocity in order not to accumulate too much heat on one side. Moreover, its orbit must be sufficiently circular to keep it from ever getting too close to its sun. Finally, its sun, unlike many stars we know of, must itself remain very stable in temperature over enormous periods.

In addition, any planet on which life as we know it exists must be of moderate mass. For if too small, like Mercury, its atmosphere and water would not be held down strongly enough by gravitation and would have evaporated off into space. And if too large, like Jupiter or Neptune, the planet would have prevented even its free hydrogen from evaporating. In that case chemical reactions favorable for life, even if started, would tend to be swamped out by the deep and all-pervading hydrogen quilt.

It has been estimated that even though all these conditions must hold at once there must be among the hundred billion or so stars of our galaxy several millions, at a low minimum reckoning, that would have one or more planets affording an appropriate setting in which living things might originate and sustain themselves. But how is it now thought that this origination could have taken place?

To understand this matter, let us first take into consideration the fact that even in stars like our sun, that have a fair amount of the heavier elements, hydrogen is still greatly predominant. This must have been true likewise in the early stages of all our sun's planets, since they and the sun were derived from one common cloud of matter. The great excess of hydrogen would react with most of the other elements present that are necessary for life, such as oxygen, carbon, and nitrogen. As a result simple compounds would be formed of these other elements with the hydrogen, such as, for oxygen, water, for carbon, methane, and for nitrogen, ammonia. On a planet having a mass and temperature somewhat like the earth's these molecules are heavy enough to be held down within its crust, ocean, and atmosphere, while the free hydrogen, as we have noted already, is light enough soon to evaporate off into space.

Now these hydrogen compounds, or "hydrides," will be exposed to tiny bolts of high-intensity energy of several kinds. Those in the atmosphere will be subjected in greatest measure to ultra-violet light from the sun, and to a lesser extent to strokes of lightning, and both those in the atmosphere and in the crust will be subjected to a small but persistent bombardment with ionizing radiation that is similar in its action to X-rays but is derived from cosmic rays, solar rays, and radioactive substances of the earth itself. All of these agents, brought to bear on the mixture of simple hydrides, have the effect of combining them together, so as to form larger, more complex molecules, in part oxidized. That is, organic compounds of diverse types are brought into being.

Thus, it was shown by Stanley Miller, when he was working as a student of Harold Urey's at the latter's University of Chicago laboratory, that when electric discharges are passed through a mixture of water vapor, methane, and ammonia, various amino acids (the building blocks of protein) and other organic molecules are produced. Moreover, Dr. Melvin Calvin of the University of California, on analyzing meteorites that had fallen to the earth from interplanetary space, found that some of them contained various organic compounds. Included among these were even those built in the form of rings and double rings composed of both nitrogen and carbon (and therefore called heterocyclic). They were, in fact, closely akin to those structures, called purines and pyrimidines, which form the most distinctive part of the hereditary chemical core, the nucleic acid, of all living things. So we see that the necessary precursors of those types of organic molecules that play the most essential role in life, namely, the amino acids that are precursors to the protein, and the purines and pyrimidines that are precursors to the nucleic acid, are both formed by natural processes that take place under primitive conditions.*

In the atmosphere of the primitive earth, before it contained free oxygen, the sun's active ultraviolet rays penetrated in much greater abundance than they do today. For the free oxygen of our present air, existing even at great heights, is converted by the ul-

*Investigators at Fordham University are recently (March, 1961) reported to have found in one meteorite an abundance of long hydrocarbons, in proportions like those in waxes derived from earthly organisms. They are inclined to the view that these represent the remains of actual living things that evolved elsewhere, rather than preliving organic material.

traviolet into ozone, and this acts as an opaque screen, high up, that shuts most of the ultraviolet off from the lower levels of air and from the earth's surface. In early times, therefore, the ultraviolet reached deeply through to cause the formation of the organic molecules mentioned and, continuing to act on them, tended to combine them into still larger, more complex forms. Although the ultraviolet would eventually have disintegrated them also, the heavier molecules tended continually to settle down onto the land and there to become covered up, or, more often, settled into the water.

In these situations the organic molecules were better protected from breakdown, and were subjected, instead, to churnings and mixings with one another. Thus the primitive ocean, accumulating ever more of them, must gradually have become transformed into what Haldane has called a "soup." And in this soup all sorts of natural experiments in organic chemistry were carried out so as to form ever larger, more complicated molecules and aggregations of molecules. Thus our earth must have acquired all the chemical preconditions for the origin of life.

[illegible]. *The Origin of Life**

What the essence of this great event consisted in is a matter that has had much light thrown on it in the last few years. But first let us review what had previously been known along these lines. At the heart of all living things on our planet is the material of heredity. This exists in the form of the microscopic threadlike bodies called chromosomes that are present in every cell. It is these chromosomes that are passed on down from each generation to the next. They carry, in their thousands of differentiated parts or genes, that are arranged in line in them like beads in a chain, the complicated specifications that control, through their chemical reactions, the development of each new body, or offspring. It is these chromosomes that reproduce their like before any cell reproduces, and thus enable each daughter cell to grow by fashioning its other materials, or protoplasm in the accepted pattern according to the given specifications.

And it is also these chromosomes which, undergoing occasional sudden changes in their inner composition, called mutations, in consequence of accidental ultramicroscopic encounters, give rise to new varieties, which in turn transmit their new characteristics to their descendants. If these varieties happen, by a rare accident, to be well fitted to survive and to multiply, they can serve as a stepping stone in the long step-by-step evolution of ever higher, more complicated forms of life.

Only in the last five or ten years has it become possible to represent these facts in the formulae of chemistry. It has become clear that the inner material of the chromosome, that which specifies what the rest of the cell shall be, that which reproduces itself, and that which mutates so as to make evolution possible, consists of nothing more nor less than a chain-molecule of nucleic acid. The individual links, called nucleotides, are of only four types in any given case, and it is their exact arrangement in line, single file, that determines the kind of chemical activity, or specification, each group of them has. A nucleotide itself consists primarily of one of the rings or double-rings containing nitrogen and carbon that we have already mentioned, called pyrimidines and purines, of any of their four types, attached to a simple sugar, and this again to a phosphoric acid group.

The way they reproduce, as first worked out by Watson and Crick in 1953, is by means of each nucleotide fastening down next to itself an appropriate nucleotide of just the right one of the three other types from among all four types that were floating free in the medium about it. The chosen one may be considered as its partner or complement, for each of the two kinds of purines or double rings has an affinity for a particular one of the two kinds of pyrimidines, or single rings. By becoming thus attached to the original chain of nucleotides a whole new row of them, exactly complementary to the first one, becomes aggregated, and these become hooked together into a chain. Later the new and old chains become separated, and each repeats the process of forming a new chain complementary to itself. Now, the complement to the complement is of course identical in nature with the original chain. In this way, through two steps, an exact replication of the original chain has been brought about. This, then, is the crucial process in reproduction.

*For a further discussion of this subject, with references, see my article in *Perspectives in Biology and Medicine*, Autumn, 1961.

It has also become evident that what a mutation usually consists of is a substitution of a different one of the four nucleotides in a given position in the place of the nucleotide already there. This could occur either as a mistake in their selection of complements during their reproduction, or by an accidental alteration or "swapping" of material at some point in an already formed chain. Naturally the altered arrangement tends to perpetuate itself through the further acts of chromosome reproduction, and so a new variety may come to make its bid for power.

That even a small chain of a few nucleotides, artificially put together in the laboratory, is capable in a test tube, under suitable conditions (as yet requiring just one enzyme), of gathering to itself free-floating nucleotides from the medium about it, and thus of reproducing itself to an unlimited extent, was recently demonstrated by Kornberg and by Ochoa. This was the feat which in 1959 won them a Nobel award. But it is an event that must also have occurred naturally in earth's primeval soup.

This step represents the critical one in the origination of life, since from that point onward natural selection of the Darwinian type would in a state of nature inevitably take over. It would do so by selecting those chains in which the mutations in number and arrangement of nucleotides had happened to give them greater stability, together with such chemical influences on other substances about them as would enhance their own powers of multiplication. Thus, gradually, the nucleotide chains came to have ever more profound effects on the molecules of amino acids and other surrounding materials, effects that remodelled, assembled, and integrated them into proteins and other accessory substances helpful to the chains themselves in their competition with one another for survival and reproduction. Thus, step by small step, that enormously complicated system which we call protoplasm was gradually fashioned, as helpful mutations continued to accumulate in the evolving nucleotide-chains or chromosomes.

Despite the inevitability of the process whereby the chromosome primordia, once set going, would gradually come to organize that workshop of theirs that we call protoplasm, whereby they carry out ever more marvellous operations in their own behalf, nevertheless the exact series of steps taken in this evolution are by no means inevitable. For just what mutations happen and become established will depend on many accidental circumstances, and there are surely many different possible pathways that the course of organization could take. Therefore, while we should recognize that life, in the form of material similar in its properties to chromosomes, could arise on any moderately warm planet whose materials were like those on our primitive earth, nevertheless we should also recognize that the further progress of that life into something akin to protoplasmic form, and then beyond that into still higher manifestations, must have had a multitude of different directions open to it. Thus, even though life elsewhere may be based in a core that is much like a chain of nucleotides, and though this core may have established chains of amino acids that we call proteins (some of enzymatic action) to serve as its second-in-command over the operations of the now living matter, nevertheless it is to be expected that from there on, if not earlier, the biochemistry would be radically different, with alien substances in the place of our vitamins, sterols, and so on.

4. The Tell-Tale Cues on Mars

Corroboration of the conclusion that life arises on any planet on which even half-way suitable conditions exist is provided by observations of the planet Mars by astronomers. There it is far below freezing over most of the surface most of the time, free oxygen is very nearly or completely lacking, and water or water vapor exist only in minute amounts. Nevertheless, the drought is not complete, and the temperature becomes temperate over part of the surface towards the middle of each day. Thus a little life of a kind based, like ours, on nucleotides and proteins in a water solution would seem to be possible.

As has long been known, telescopic observation shows fairly extensive dark grayish areas, although most of the surface is of a reddish-yellow hue suggestive of sandy deserts. Moreover, the dark areas, unlike the reddish ones, change in shade with the seasons in a manner very suggestive of the grayish-green vegetation that exists at high latitudes and high altitudes on our earth. For when winter

approaches on Mars these darker areas turn brownish, and as spring advances they become gray or grayish-green again. It is especially noteworthy that in summer, dust or sand seem occasionally to be blown over parts of the dark areas, obscuring them, yet before many days elapse the overlying layer seems to fade away as though it had somehow become swept off or grown over.

At the observatory of the Pic du Midi, at Lake Geneva, observations of the polarization of the light reflected from the dark areas, at various angles in relation to the angle of the incident light, have given evidence that the surface is peppered with a host of tiny objects. It can be reckoned that in winter these are somewhat smaller, on the average, than a tenth of a millimeter, so that if we were on the spot they would be only just visible to our naked eye. But as the season advances towards summer the polarization changes in such a way as to lead to the conclusion that these objects have grown to about ten times their winter size. And so it goes, back and forth, as the seasons succeed one another and as the coloration changes concurrently.

The most recent findings are those that have been made by detailed examination of the infra-red light reflected from the two kinds of areas of Mars. In these examinations the light, after having been received through a telescope, is passed through a spectroscope in the usual way, in order to be spread apart into its different wave-lengths. It is then found that there are dark bands, indicating the absence of light of given wave-lengths, in particular positions along this spectrum. The missing light-waves had of course been blocked by the material on the planet's surface. Now the position of these bands corresponds exactly with those of the dark bands obtained when infra-red light is reflected from certain known compounds here on earth and examined in the same way. In the case of Mars, these absorption bands are found only in the reflections from the dark areas. As for the compounds on earth that give the same bands, they are all organic compounds, of a type which on earth today are manufactured only by living things, and the structure in these compounds responsible for these bands is a certain type of chemical bond between carbon and hydrogen. This is as deep as we have yet been able to see into the nature of our sister planet's mysterious dark areas.[1]

It is true that no one of these lines of evidence is conclusive by itself. Taken together, however, they make up a very weighty body of testimony for the presence of living things on Mars. Now consider that this is the only planet in our solar system, other than our earth, on which the conditions of temperature and composition would allow living things composed of carbon compounds to exist actively. Then the fact that these consistent signs of life have been obtained from this very planet, despite the *relative* unfavorability of its conditions, is seen to constitute a powerful argument that life will arise and evolve anywhere in the universe that a setting exists which is only half-way suitable for it to struggle along in.[2]

No doubt the life on Mars is far more meager and more primitive than that on earth. Not only has the room in which it could live been far smaller there, but the lower temperature, lesser illumination, and dearth of water and atmosphere must limit the rate of chemical turnover to a small fraction of ours, and along with this must correspondingly limit the rate of evolution. True, there must once have been more water on Mars, before most of it had evaporated off, and life must then have been more flourishing, though incomparably less so, at its best, than on our earth. But our earth in turn may be poor in life compared with what exists on some of the even more favored planets of other stars.

5. The Possibility of Life Based on Other Materials

In any place in which living things have evolved, the primitive living matter must, like

[1]According to letters from N. B. Colthup and W. M. Sinton in *Science*, Aug. 25, 1961, two bands point especially to acetaldehyde, which on earth is a product of anaerobic catabolism, while another band seems to indicate carbohydrates and/or proteins.

[2]However, Anders has recently argued in *Science*, April 14, 1961, that oftener than once in a million years the earth is hit by asteroids or meteorites so large that their impact could throw off fragments of the earth's surface with escape velocity. Some of these, harboring microorganisms, could seed other planets in our own solar system, and possibly even planets of other stars. Reciprocally, our own microorganisms might originally have been derived from elsewhere. Thus, actual biochemical comparisons will be needed for throwing light on whether life forms on earth and Mars, or on any two accessible planets, are of common or independent origin.

the chromosomes we know, have the faculty of replicating, by arranging particles taken from the medium about it into a pattern like its own, and the faculty of having occasional mutations in its pattern, which are then subject to replication themselves. For, as we have seen, these procedures inevitably result in that accumulation of helpful mutations whereby more highly organized beings gradually take shape. However, we may well ask, could there be some other kind of potent chemical materials than nucleotide-chains that like the latter are able, under some circumstances, to engage in replication, and to undergo mutations some of which are helpful to their replication, and that consequently have the tendency to evolve to ever higher forms? In other words, must all life everywhere be based on nucleotides, that construct proteins and work in a water medium?

It has been imagined, for example, that under much colder conditions, where ammonia is liquid but water solid, there might be complicated replicating molecules other than nucleotide-chains, immersed in the ammonia, and serving as the basis of living things quite different in their building blocks from those we know. Again, at temperatures so high that water is vaporized, might not some type of compound based in part on silicon instead of carbon become organized in a still different medium, liquid at that temperature, so as to form still another type of life?

Although such speculations cannot be categorically dismissed, there is no factual basis for them, and no combinations of compounds and medium have been conceived that could work as imagined. It is true that the relevant chemistry for forming a judgment is as yet very undeveloped, and that we have only recently understood the bare outlines of how our own nucleotides operate to make our own type of life possible. Nevertheless, even on our earth very diverse physical and chemical conditions occur in different situations, and we have nowhere found a suggestion that any other kind of life exists or has existed anywhere on earth, other than that based in nucleotide-chains. Obviously it is the highly special structure of these nucleotides that gives them the faculties on which the evolution of our life has been based. We may therefore "keep our fingers crossed" about the possibility of life of wholly different constitution than that on our earth having arisen elsewhere, while at the same time we should admit that in the light of present knowledge this hypothesis seems highly unlikely.

As for the nature of life that exists under a range of conditions not too different from those on earth, we should within the lifetimes of most of the readers of this article have some solid facts to help us judge whether or not such life is likely to be founded on material different from that of nucleotide-chains. For surely, if civilization manages to avoid destroying itself by war, we will long before the turn of the next century have succeeded in reaching Mars and in probing into the nature of its organisms. Thereupon will begin the most exciting story in the exploration of life that has ever happened to man, except of course for the story that is going on right now in those laboratories of ours where biochemists and geneticists are disentangling the warp and woof of which our own earthly life is composed.

Even if the living matter of Mars and of all other worlds on which life occurs has been restricted in its origin to chains of nucleotides, or to something much like them, working in water, there would still be very different pathways to its further evolution. By analogy with earth's life we would expect that the next step would be the action of the nucleotides in picking out from the medium molecules of amino acids, which are the building blocks of protein, and the stringing of them together to make protein. But we cannot be sure. And even if it were the case, it would not follow that all these amino acids were just the same in their construction as the twenty different kinds that our nucleotide-chains make, for there are many more types possible. One difference might be that on Mars some or all of the amino acids in the proteins were mirror-images of ours, twisting light to the right instead of, like ours, all to the left. This is but one little example.

Moreover, as has been mentioned previously, the secondary, more specialized materials, including vitamins and other prosthetic groups, as they are called, hormones, toxins, etc., and even the common materials corresponding or analogous to carbohydrates, fats, and other lipids, are likely to be much more different from those of earthly organisms than those

of earthly organisms are from one another. For those in earthly organisms are on the whole in surprising agreement, as if the common ancestor of all species on earth had already acquired most of our own biochemical composition before the tree of evolution put forth the branches that we find on earth today. Thus, while the substances of practically all other organisms, animal, plant, or microbe, found on earth can be digested and used by us, at least after cooking, being interconvertible one into the other, this is not to be expected of life forms evolved after an independent origination of life on any other planet. We would not be able to use them as food nor could they use us. In fact, we would be likely to be mutually poisonous to one another.

6. Some Expected Points of Agreement

However that may be, life on any other planet having our range of conditions would eventually have come to derive nearly all of its energy by the absorption of the sunlight by means of pigments. Most likely these pigments would be porphyrins, like those in the chlorophyll of earth's plants, although it seems unlikely that the complicated structure of this chlorophyll would be exactly duplicated somewhere else. Once this means of capturing energy and therewith synthesizing the compounds needed had been achieved, there would inevitably be a tendency for organisms to split, as they did on earth, into the synthesizers or plant-like types and the predatory or animal-like ones. The development of plant-animals combining both modes of life, that one sometimes reads about in science fiction, is very improbable. For an enormous surface is needed to gather enough light to maintain a fair-sized animal, but such an organism would not be compact enough to have the movements necessary for an animal. Thus for plants above microscopic size there must be an emphasis on reaching out and absorbing the minerals, water, carbon dioxide, and sunlight needed. In the case of land plants this means that there must be roots for the minerals and water, leaves for the carbon dioxide and sunlight, and a supporting structure between to hold them together and conduct materials between them. However, within these specifications there can be an enormous latitude of types, especially with regard to means of disseminating the products of reproduction.

In some situations, size is an advantage to a plant or animal. However, it raises difficulties. For example, simple diffusion of materials is no longer effective enough in transport of materials over distances larger than microscopic ones. For larger masses, compartmentalization into more or less specialized units, or cells, with spaces between or within them for transport, becomes advantagous. We would therefore expect this multicellular condition to develop on any world having highly organized life. At first the multiple cells would tend to be arranged in thin layers in order to allow sufficiently ready in-go and out-go of materials from their surfaces. Further complication would tend to lead to foldings of these layers and migrations from them, as we find in the development of our own higher organisms from the egg to the adult stage.

In the evolution of animals, unlike that of plants, the emphasis tends to be on effective motor response to allow them to get food and to keep them from being themselves used as food. Thus it is advantagous for the more advanced animals to develop improved sensory and coördinating systems, and to have a readily maneuverable and powerful and therefore fairly compact body. The resulting tendency to bulkiness calls for increasing servicing of the inner parts, that is, for the development of systems, much more complicated than those of plants, for taking in and processing the food and fluids, for converting and distributing them, and for collecting and eliminating the wastes.

7. Multiple Solutions for Higher Stages

But although higher organisms on other planets would almost inevitably have undergone all these developments in some form they may be expected to have followed radically different courses in regard to many of the features. Illustrations of such dissimilarities among fairly advanced animals of widely different types on earth, such as starfish, beetle, octopus, and fish, are familiar to everyone who has studied a little zoology. How much greater, then, might such differences be between the forms of earth and those of another planet. These differences, affecting their whole internal economy, in-

cluding the biochemistry within their cells, would also be expressed in their gross anatomy and in their outer form.

Just as in the evolution of the biochemical system, so too in that of organs, tissues, and the general ensemble of any organism of a moderately high or high stage of advancement, innumerable steps of progression have been mounted in succession. Among these steps there have often been some that later proved to have been deflections or even descents from the general course. Features have also been included that met some more immediate need but after a while, as when the organism's way of life or other features had changed, turned out to be useful in a very different way and thereupon became subjected to further evolution in that other direction. For natural selection cannot see ahead to later possibilities. It is opportunistic and therefore subject in some situations to long periods of marking time and to occasional lucky turnings of a corner that are followed by a burst of progress along one or more new lines.

Just what step will be taken at a particular point is sometimes a matter of accident: of what mutation manages to take hold, and then what combination of mutations, until some novel structure or manner of functioning is thereby brought into being that acts as a key to open up an important new way of living. This in turn can usher in a whole new series of developments, centered about the given key innovation. A frequently cited example of this kind of thing is the appearance of a structure that can begin to serve for transportation through the air and so initiates the evolution of wings and, secondarily, of all sorts of other changes in adaptation to the life of a flier.

Another unusual key change, that occurred in the remote ancestors of the starfish group (echinoderms), was the formation of tubular projections (tube feet), arising from five or more arms that radiated out like spokes on a wheel. The arms were used in getting food, and the tube feet, which passed the food along to the mouth in the middle, were worked by means of changing water pressure inside them. This pressure was regulated by the contraction or expansion of syringe-like bulbs inside the body that were connected with the tube feet. Only on this one occasion in our animal kingdom of earth did this combination of structures arise. However, having once arisen, it was eventually taken advantage of both for grasping and pulling (when suckers were developed at the ends of the tube feet), and for a distinctive kind of locomotion, combined with aggression. It made possible, for example, the overcoming of such slow-moving prey as clams. In time, the form and all the other bodily systems of these animals became radically reorganized so as to take better advantage of these unique tube feet, and so a whole phylum, or great group of species, took shape, that are modelled along lines quite different from those of any other earthly creature.

Another key structure has been the jointed external shell, continued on to appendages also having joints, that arose in the group ancestral to crustacea and their relatives. To this system of jointed armor very much else in the advanced organization of these active aggressors is adjusted.

Contrasting with this, the molluscs, which in the distant past had come from the same stem as the crustacea, did not have their shell extend to their appendages. Instead, in the more typical molluscs the shell early became united into one or two large protective covers, attached to a fold of skin or "mantle," more or less separated from the body, that enabled the shell to envelope much or all of the body. Effectively defended in this way, these animals could largely dispense with high mobility if they concentrated on the scouring of the water or surfaces about them for microscopic prey or plant material.

However, one branch of the molluscs developed an important new key structure, in the shape of uncovered protrusions or tentacles that projected in front. These tentacles gave their possessors (cephalopods) such great potentialities for active and mobile aggression, as well as for defense, that the shell, increasingly a liability for these creatures, dwindled in the higher types. At the same time, such an impetus was thereby given to the selection of ever better motor, sensory, and nervous systems, and to the efficient servicing of the comparatively massive body, that the resultant group of squids and octopuses may be considered to be just as highly developed, after their fashion, as the group of

backboned animals (vertebrates) to which we are proud to belong. However, since their organs have evolved so independently of ours their anatomy, in spite of showing many striking analogies to ours, is built on a fundamentally different pattern.

Our own vertebrate pattern can be properly understood only by having in mind that it started out as a torpedo-like or eel-like shape supported by a somewhat flexible inner rod; that it was soon provided all over with a protective covering of teeth, which in the jawed mouth, by becoming enlarged, furnished a very effective instrument of aggression; and that for purposes of stabilization in swimming, paired fins were developed which could later become modified into limbs. Here too, then, was a basis for the further improvement of parts in the interests of better maneuverability, better powers of offense and defense, and reactions ever more effectively adjusted to the changing events in the environment. In this group also, therefore, there was a special premium put on developments that improved the sensory and the nervous systems, and in this way we ourselves at last came into being.

8. The Bizarreness of the Right and Proper

Many key developments like those we have been considering seem to have arisen in a successful way only once or twice in all the history of life on earth, and their beginnings must therefore have involved a very accidental combination of circumstances. This being the case, there must have been very many more key developments possible, of just as great potential significance, which never did occur on our earth, at least not in a successful manner. On any other planet that supported life one would therefore expect to find some other developments, together with all the accessory features that they had given occasion for.

Thus, even without taking into consideration the great differences in the biochemical basis and the lower evolutionary stages between life somewhere else and that on earth, the higher developments there would be expected to be at least as different from ours in their general pattern and workings as the ordinary dog, the tarantula, and the chambered nautilus of our world are different from one another. Certainly, then, we could not classify the organisms there within any of the earth's grand categories or phyla, such as vertebrates, molluscs, or flowering plants, much less within any of the narrower divisions, such as the classes, orders, families, or species known on earth. Viewed in this light, we see how utterly foolish it would be for us to expect to find human beings to have evolved on any other world.

It is most naïve of human beings to assume that the human type, or any other type familiar to them on this little planet, is the right and proper type, and that nature has been subjected to some sort of irresistible compulsion to produce it. Looked at in a larger light, we humans and all our companion species of here-existing animals and plants are most bizarre, as any visitor from elsewhere would readily testify to. That is, although our organizations are full of intricacies that work wondrously in relation to one another, and although the over-all structure of some parts, such as the eye, is the only workable arrangement that could have been developed from the basis with which it began, nevertheless many other features of the pattern represent very gratuitous arrangements or makeshifts that we try to make the best of.

Take, for instance, the way we and other land vertebrates breathe air. It is very inconvenient to have it come through the mouth or, coming through the nose, that it should have to share a part of the same passageway as must serve also for food. Thus, the land snail, whose lung has a passageway and opening quite distinct from its food canal, is much better off in this respect. So too is the grasshopper or other insect, which breathes through portholes placed near the organs to be aerated, or which as in the case of aquatic larvae breathes through openings located at the hind end, that can project out while the mouth continues to feed comfortably down below.

Our own inconvenient arrangement harks back to the time when as fish both our oxygen and our food were in the water that came in via our mouth, and we gulped air for our swim bladder. In non-vertebrate water-breathers, on the other hand, the gills have not been in slits of the food canal, and have no connection with it except in the

case of the sea-cucumbers that breathe through their rectum. In most other gilled animals the gills, being tender, lie tucked away under the abdomen or protected in a fold or under a mantle.

Let us proceed a little further in considering the strange combination of features that our own mouth represents. Besides acting to take in both food and oxygen, it serves the majority of the vertebrates as their most powerful weapon and at the same time as their deftest organ of manipulation—activities usually assigned by other progressive phyla to specially constructed appendages. In addition, in most land vertebrates the mouth has the peculiar function of emitting sounds, while other animals that make noises do so by quite different means, as by fiddling, buzzing, or strumming.

Finally, in human beings and their relatives the mouth is also used for the important purpose of expressing their feelings, as through scowls, sneers, smiles, and so on. Although these modes of expresion seem natural to us, being inherited in us and even present in other mammals, as Darwin pointed out in his fascinating book, "The Expression of the Emotions in Man and Animals," nevertheless the meanings they and our other bodily signals convey to us would not be apprehended by any alien creature who had not had an opportunity to learn them.

In short, then, the alien would find it most remarkable that we had an organ combining the requirements of breathing, ingesting, tasting, chewing, biting, and on occasion fighting, helping to thread needles, yelling, whistling, lecturing, and grimacing. He might well have separate organs for all these purposes, located in diverse parts of his body, and would consider as awkward and primitive our imperfect separation of these functions. Thus, for the science fictionist to picture the alien with an absurdly all-purpose mouth like ours, as he usually does, is a prime example of the prevalence among our supposed intelligentsia of utter unsophistication in regard to basic biological matters.

Our example of the mouth is by no means the most striking of its kind that might be given. The whole concept of the head as we think of it is pretty much a man-centered or rather, a vertebrate-centered one, as one realizes when examining a spider, octopus, or crab, in which the head and much of the trunk are merged. Moreover, neither the organs of hearing nor of smell need be near the brain or the mouth—as witness the grasshopper, which has its ears on its abdomen, and the fly, which smells and tastes with the tips of its feet. Again, consider the scallop, a headless but alert mollusc that can swim actively and whose many eyes, structured much like ours, are arranged in a long row on the mantle, just beyond the edge of each shell. So we could go on and on, citing the seemingly outré of this very planet earth as evidence of our own singularity.

There are other important object lessons to be derived from a comparison of sense organs, and more especially of eyes. Advanced eyes built on principles basically like our own, complete with lid, cornea, adjustable lens, iris diaphragm, retina, absorbing layer, etc., have been evolved independently in several very different lines of descent, among them the octopus-squid group and, though less perfectly, the group of scallops just mentioned. They proceeded from similar beginnings but took a different evolutionary course, whereby however they reached essentially the same final form. Nevertheless, eyes using entirely different principles of image formation have also been evolved, such as the convexly radiating set of tubes that form the insect's compound eye, the pinhole type of the nautilus, and the scanning eye of the snail. But we know at least one other principle that would be effective, the reflector type that is embodied in some of our telescopes, which it happens has never yet been hit upon by earthly organisms though they do use accurately curved reflectors for some other purposes.

As for the kind of radiation to which known eyes are sensitive, we may note that many animals, for instance bees and some butterflies, are sensitive to a range of colors which, by comparison with our range, is displaced toward the shorter wave lengths, so that they fail to see the reds but do see well into the ultraviolet that we are blind to. The snail's eye is very sensitive to X-rays and other ionizing radiation. The rattlesnake and its relatives have delicate directional infra-red detectors in the two special pits on their

head, by which they can sense the presence and position of mammals and birds. The king crab is one among various creatures that can distinguish the direction of polarization of light, somewhat as we can its color. Water currents and vibrations of different types, unlike or beyond the sound waves we hear, are also sensed by special organs in diverse organisms. And there is no doubt that there are in earthly creatures senses, and elaborations of senses, that we are as yet unaware of.

I draw the line, however, at the idea of telepathy for any earthly creatures as at present built. It would take me far too long to explain my reasons for this view, except to say that it implies phenomena quite contradictory to all we know about the ways of working of the nervous systems of man or earthly animals. Nevertheless, there might well be natural means of communication between creatures that had developed elsewhere, using physical channels of transmission and reception to which we are insensitive. We might at first regard these beings as telepathic. Similarly, a group of people all of whom were deaf might infer that we communicate telepathically with one another when we speak.

In the matter of communication, we are apt to take it for granted that the natural method is by sound, although we do use sight also. Ants convey messages through touch by motions of their antennae. Bees use something akin to pantomime. For all we know, squids may be signalling very elaborately when they control the colored patterns that shimmer over their surfaces in such varied forms, and it is even possible that they can do this at night and in the dark depths of ocean when they cause their skin to light up with moving fluorescent designs. All this should make us more broadminded as well as cautious when we try to imagine the ways in which a fairly intelligent creature of another planet would behave.

9. A Few Rules of Inference

There are, of course, some principles that can help us in inferring what types of life might have developed on a planet of known temperature, mass, and composition. The smaller and less favorable the area on it for the flourishing of life, and the shorter the time since life could begin on it, the less advanced and the less diversified that life will necessarily be. Again, the greater the planet's mass, and therefore the force of its gravity, the shorter and stockier its land animals will tend to be, to bear their own weight, while conversely lesser gravity would tend to lead to slimness. Greater gravity would however tend to go with an atmosphere disproportionately dense, even in relation to the weight of objects, and so it would be favorable for the development of flying, and perhaps even for balloon-like lifting organs, secreting hydrogen or methane. However, we must remember that the force of gravity is relatively unimportant for aquatic forms, since the water tends to support them.

Most of earth's highest developments among animals, and more especially among plants, took place in the more varied and variable environments to be found on land. Yet life must have its origin in water. Therefore, other things being equal, the higher developments of life will be found on those planets that have considerable areas of both water and land.

Such planets might be very exceptional, however, if the hypothesis, now somewhat out of favor, should prove to be correct after all, according to which our great ocean basins trace their origin to the tearing of the moon out of the earth's crust in the Pacific area by means of the sun's tidal action at an early time. For it was the same process as dug the ocean basins that conversely must have left the continents high and dry. However, only certain very exact quantitative relations between the earth's and sun's mass and the period of the earth's rotation on its axis, could have led to a cataclysm like that here conceived. Sir George Darwin believed his reckoning showed that the necessary relations did hold in this instance. But, if so, an event of this kind could have happened very seldom elsewhere. Hence, if this is really what it usually takes to raise continents, very few planets indeed must be provided with them. The moons attending other planets in our solar system were almost certainly not formed in this way. On this theory, then, life on the great majority of planets would be confined to aquatic types, plus any with drastic innovations which had enabled them (like flying fish) to soar out of the water or (like the

argonaut or masses of seaweeds) to make floats for themselves or for organisms associated with them.

10. What of Intelligent Life Elsewhere?

We may be sure that in the competitive struggle of higher animals for existence, on any world, the effectiveness of their sensory and coordinating systems will play an important role in determining their success. For the more effective these systems are, the more likely are the animals to carry out movements that enable them to take better advantage of opportunities presented by their environment, and to guard themselves better against its dangers. Thus, through the survival of mutations helpful in these respects, their sensory and nervous systems will tend to accumulate a succession of improvements, including reflexes and instincts that result in ever more serviceable reactions.

However, as we know from the evolution of behavior in our own world, much additional advantage may be gained if the nervous system is so constituted as to allow the modification of these reactions in conformity with the individual's own experience. This process, the neurological basis for which is not yet understood (although it is said that the results of it may to some extent be imitated in certain artificial computers), is on its lower levels termed "conditioning" and, as it becomes more highly developed, "association," "conscious learning," and, finally, "intelligence."

It is hard to judge how much of an innovation is required for establishing the *rudiment* of the mechanism that allows conditioning. For we do not know how far down in the scale of our animal life it is present and so do not know if it arose just once or had a multiple origin. Yet where it is very rudimentary, as in some worms, it seems to be of so little use that it would hardly have become established in evolution unless it had at that time involved a fairly simple development. At any rate, we do know that as evolution continued several different lines of animals that we may call progressive all carried the development of conditioning to a far higher degree. These included more especially the lines with jointed appendages (notably crustacea, insects, and the spider group), the active tentacled molluscs (squids and octopuses), and of course our own group of vertebrates. In view of these multiple parallel developments, all of them such notable ones, it seems very likely that in the evolution of higher, more active animals on practically any world, association, learning, and intelligence would at last make their appearance.

Even such higher levels of understanding as are evidenced by the carrying out of constructive operations nicely adapted to individualized situations, the use of inanimate materials as tools, and the exercise of foresight in making plans are, on this earth, by no means confined to man or even to mammals or the vertebrates. To refute the idea that they are, we need only call attention to the engineering of the beavers, the way some birds build their nests, and some spiders their webs, to the strategies used by wolves, foxes, and raccoons in hunting and in eluding pursuit, to the way a wasp on occasion selects a pebble and then pounds down the earth on its nest with it, or to the practice of the octopus in dropping a stone between the shells of an open clam so that it can then safely insert its tentacle and extract the soft body. There is much more than mere instinct in all these activities.

However, it is only in our own line of descent, of all those on earth, that intelligence has advanced far enough to allow elaborate communication to take place, and that at the same time social feelings have become so well developed as to result in the ever more effective transfer of understanding and skills by example and precept, from individuals to their companions, and from elders to youngsters. This is a process which, in the large, we call "cultural evolution," for it goes on and on. In other words, biological evolution has to proceed very far before the native intelligence, combined with sociality, reaches such a level as to permit the social advances which engender civilization and eventually science. Yet I am convinced that, if man should disappear, a creature something like one of those I have named would eventually succeed in attaining that level on its own. But so long as man is here, he holds that door closed to it.

On another planet having conditions as favorable for animal life as ours, there is

every reason to expect that in a comparable period evolution would have resulted in as high intelligence as in our own more intelligent animals, and that in time one of these would have stepped over the threshold into the realm of culture, civilization, and science. As we have seen, such a creature could not be anything like a man or even a vertebrate in his bodily construction or physiology. Moreover, on different worlds he would surely be most diverse in regard to form, general behavior, and methods of natural communication (although he would surely have some such methods). To picture him as probably bipedal reveals a naïve egoism, although he would of course have manipulable appendages that were freed from the duties of locomotion. As for his intelligence, however, despite its independent origin, it would certainly be capable of achieving much mutual understanding with our own, since both had been evolved to deal usefully with a world in which the same physicochemical and general biological principles operate.

Would he in most cases be ahead of us or behind us in civilization, knowledge, and techniques? That is a question which a little consideration will show to be easier to answer than it would at first sight seem to be.

Let us first recall that known fossils show our earth to have had cellular, protoplasmic life more than two and a half billion years ago. However, men with a culture higher than that of food gathering seem to have existed for not more than 12,000 years. This, then, is only a two-hundred-thousandth part, or less, of the whole time our biological evolution has consumed. But astronomical evidence indicates that our sun and earth are likely to continue with approximately their present temperature and other natural physicochemical conditions for a period far longer than two and a half billion years into the future. Thus, if man uses his great gifts wisely he is likely to be able to continue his march at least as long as life has already existed on earth. During all that time he would have the opportunity to continue advancing in knowledge, in techniques, and in regard to his inner being and his social relations, at a self-controlled pace. Undoubtedly he would also extend this progress to his own genetic constitution, as a result of his own free choice to do so. This genetic advance would in its turn allow him to reach still higher levels of civilization and of control of the world about him and himself.

Now if, as some astronomers conclude, many of the stars and planets in our galaxy are much younger, and many others much older than our sun, with our sun not far from the average in its age, it is easy to see that worlds having life, if similarly distributed in age, would include about as many older as younger than ours. If then their *average* age was some five billion years, as ours is, and their range of ages such that the average difference between two taken at random was one billion years, we can see that as often as not another life-bearing world would be a billion years behind us or a billion years ahead of us. A billion years behind us would probably put us back at about the level of jelly fish, but a billion years ahead—what would THAT be?

In the light of these considerations, the finding of a planet whose highest life-form corresponded with something between our beginning civilization of 12,000 years ago and one of 12,000 years more advanced than ours would be like having the good fortune to draw the one lucky number out of eighty thousand. For this range of 24,000 years is only an eighty thousandth part of the two billion years range—a billion in either direction—that we are likely to be dealing with.

In other words, in only one out of 80,000 planets having life would we be likely to find it at a stage having a civilization at all comparable to ours (though personally I would not think of a civilization a mere thousand years ahead of us as "comparable"). In half of the rest life would not yet have reached the stage of civilization, usually not that of any culture at all. But in the other half it would be so far ahead of us that we would stand completely abashed before it. What that kind of contact would mean for us is a matter that might be speculated about at great length but with little satisfaction.

11. Why Have We Found No Sign of THEM?

There is, however, one very jarring note in this composition. If there are really so many millions of worlds in our galaxy whose inhabitants are so far ahead of us, why have none

of them already settled here or at least given us any evidence that they visited here? All our life has obviously been derived from but one tree. But everywhere the law of life is to expand and to settle wherever it can. And though we are at present preparing only for interplanetary flight within our solar system we may be sure that before many generations have elapsed we shall be ready even to tackle the far vaster distances between the stars. If THEY can do all this so much better, why have they not already done so?

Before closing let us briefly go over a few of the more obvious possibilities. One is that the physicochemical organization that makes possible conditioning of a type that can later be elaborated into intelligence represents after all an extremely improbable combination of mutations. On this view, it happened only once on earth, and the intelligence of all the diverse types of higher animals mentioned really traces back to that unique beginning. So exceptional, on this view, would this event have been that it took place on only this one planet of ours or at most on only a very few of the myriads harboring life.

Then there are the cynics, the standpatters, and the oldsters who would maintain that the distances between the stars are really too great to be conquered even by the efforts of the most intrepid explorers willing to make the sacrifice of spending generations on the way. We would ourselves admit that almost surely the dream of exceeding the speed of light is an idle fantasy, like that of perpetual motion. And the time necessary for travelling at a lesser speed poses for these objectors an insuperable difficulty. Some might also maintain that the cosmic rays are too destructive (although if one had enough energy one could send a body so massive as to provide sufficient shielding). And as for other dangers, they say, we just have not discovered them yet.

Another line of thought would have it that an intelligent being after reaching a somewhat advanced stage inevitably destroys himself, if not by mass warfare or genetic neglect, then perhaps by sinking into a decadent complacency in which he philosophizes himself out of the motivation to continue his expansion or even his life. Or he might construct such advanced robots that they at last took over and yet lacked some requisites for the unlimited continuance and expansion that is characteristic of life itself.

All these interpretations are essentially pessimistic for they would limit us as well as other life forms. There is on the other hand the optimistic possibility (however improbable it may be) that we happen to be ahead of anybody else, or at least of anyone near enough in our neighborhood to have reached us as yet. In support of this idea it has been suggested that our own sun, although far from being one of the oldest stars, is one of the oldest in that third or fourth generation which alone would supply enough of the heavier elements that are needed to make possible such active life as ours. In that case we would have the edge on the others in evolution, and we will get to them before they can get to us, but they will have nothing to teach us except what we can learn by our own efforts at studying them.

Finally, let us recall another circumstance that might have given us the edge on them. If most planets that could support abundant life are rather evenly contoured, as Mars is, and are given the major inequalities of level necessary to differentiate continents from oceans only by such a cataclysm as George Darwin pictured in the supposed tearing off of our moon, then nearly all these other planets are almost completely covered by water. If that had been the case on our earth, then, as we have noted previously, most of our highest types of life, being land types, would not yet have had the opportunity to evolve. By the same reasoning the other planets that lacked continents would also have been retarded in their evolution. Whether this retardation would be sufficient to have kept even those one or two billion years older than we from reaching our present level is another matter that we might at present speculate upon fruitlessly.

Whatever the answer may be, I believe that we shall some day—and before a thousand years are up!—find out. In the meantime, we shall have plenty to do. Let us make sure, however, that we do not use these great new powers and new insights in mutual destruction. Let us also make sure that we preserve that spirit of free inquiry, free expression, free criticism, and humane con-

science which should make it possible for us to challenge space without dehumanizing ourselves in regard to our most essential values.

At this point we may well adopt the motto of the Kansas pioneers, also used later by British fliers in World War II: "*Per aspera ad astra,*" that is (rather freely rendered) "*On through the rough going and to the stars.*"

Proposed Revisions of the Constitution of NABT

The following changes have been proposed in the Constitution by the Executive Board, and these changes are noted below with the statement of the original Constitution wording preceding them. The Constitution requires that all such changes be published in the journal prior to action of the Board of Directors.

As Now Stated:

Article VII, Section 1, Chapter Affiliation.

Any active local, state or regional biology teachers association may affiliate as a chapter in this Association by conforming to the following requirements:

1. Make a formal application.
2. Hold regular meetings.
3. Must have a minimum of 25 members of NABT or at least 25 per cent of membership must be members of NABT in order to be represented on the Board of Directors.
4. Must send an annual report on their meetings.

A favorable vote of three-fourths of the Board of Directors shall be required for such sanction. The affiliating chapter agrees to comply with the then existing constitution and by-laws of this Association. Each affiliate to receive a certificate of affiliation.

Article VII, Section 2.

Any active chapter may of its own volition, by petitioning the Executive Board for such a privilege, collect the regular national association dues together with such local assessments of their chapter from their members. All national dues so collected together with a list of those contributing such dues as members shall be sent promptly to the national secretary-treasurer for credit to the individual members. Any chapter making such collections must annually submit their books to the Executive Board to be audited by the auditing committee.

Article VII, Section 3.

Any active chapter of their own volition may, by petitioning the Executive Board for such privileges, conduct the regular elections for national officers among their members that are members of the national association. In conducting such elections they must comply with the rulings of the Executive Board for such elections. The ballot must be secret. The results of such an election must be mailed immediately directly to the national secretary-treasurer. The results of such an election shall be considered as a part of the national election and the votes shall be counted together with the others submitted.

Proposed Amendment

Article VII, Section 1, Qualifications for Affiliates.

Any active local, state, or regional association of preservice or inservice teachers of biology or the biology section of science teacher associations may affiliate as a chapter of the National Association of Biology Teachers by fulfilling the following requirements:

1. The group shall make a formal application for Affiliation membership. A copy of the constitution, membership list, and summary of program or annual report shall accompany letter of application.
2. Twenty-five percent or twenty-five members of the affiliate groups shall be members of NABT.
3. The application will be reviewed by the NABT Affiliations Committee for recommendation to NABT Board of Directors.
4. Following acceptance by the Board of Directors and on receipt of the Certificate of Affiliation, the Affiliate group shall appoint a member to the NABT Board of Directors for the forthcoming national meeting.
5. The Affiliate will be urged to send reports of activities and programs to the editor of NABT News and Views.
6. In order to retain $1.00 of each NABT membership, the Affiliate shall collect the regular national dues from their members. Dues and list must be transmitted in one sum to the NABT secretary-treasurer between September 1 and January 31.
7. An Affiliate membership list should be submitted each year on or before January 31.

A favorable vote of three-fourths of the Board of Directors shall be required for such sanction. The affiliating chapter agrees to comply with the then existing constitution and by-laws of this Association. Each affiliate will receive a certificate of affiliation.

Article VII, Section 2.

Any active chapter may, of its own volition, collect the regular national association dues together with such local assessments of their chapter from their members. All national dues so collected together with a list of those contributing such dues as mem-

bers shall be sent in one sum to the national secretary-treasurer for credit to the individual members.

Article VII, Section 3.

Privileges extended to Affiliate Members shall include:

1. Cooperation with NABT in organizing local and regional meetings.
2. Attendance of NABT members at local meetings.
3. Participation of local groups in organizing NABT national and regional meetings.
4. Participation of local groups in NABT special projects, conferences, and committee activities.
5. Representation of local group on NABT Board of Directors.
6. Publication of Affiliate news items in NABT's newsletter, *News and Views.*
7. The prestige of being affiliated with the only national society of professional biology teachers.
8. Retention of $1.00 of each NABT affiliate member's dues.

How to Donate Your Body for Medical Science

A new brochure, "How to Donate Your Body for Medical Science," is available from the National Society for Medical Research, 920 S. Michigan Avenue, Chicago 5, Illinois. The 4-page booklet was written by Dr. Oliver P. Jones, Head of the Anatomy Department at the University of Buffalo Medical School and Chairman of the NSMR Committee on Anatomical Materials. The brochure reports the need of bodies for research, lists twenty-eight states which have self-determination laws which assure a donor his bequest will not be nullified by the next-of-kin; describes a simple bequest procedure utilizing a standard triplicate form provided by most medical schools, and common funeral and burial procedures. The Declaration of Consent form and a list of anatomy department chairmen at U. S. and Canadian medical schools is also available from the NSMR.

Detection

A fast on-the-spot test for detection of hazardous fallout in milk has been developed by chemists of the U. S. Atomic Energy Commission. The method, based on a series of chemical techniques, can analyze 20 samples of milk in four to five hours, as compared with the 3 or 4 weeks required for conventional analysis.

Science Student Teachers

A report has been prepared on this subject by Professor John L. Stewart, North Carolina College, Durham, on the experiences of this school in the program. A copy may be obtained by writing Dr. Stewart.

NABT and NEBA Combined Meeting

A combined meeting of NABT and the New England Biological Association was held at the Audubon Center, Bear Brook State Park, Allenstown, New Hampshire on May 27, 1961.

One session was devoted to talks by Leslie Clark, Director of the Spruce Pond Conservation Camp, and Tudor Richards, President of the New Hampshire Audubon Society. The theme was Conservation for Teachers. Following the luncheon, and business meeting, Dr. Marjorie Milne, Biology Department of the University of New Hampshire, discussed the BSCS versions. Both she and her husband worked on the BSCS program at Boulder last summer.

Miss Mildred Gutterson, New Hampshire State Membership Chairman, and Irving C. Keene, Region I Director, arranged the program.

25 College Scholarships

The Future Scientists of America Awards program for 1961-1962, sponsored by the NSTA, will give high school students an opportunity to compete for $250 college scholarships for excellence in scientific projects. These scholarships will be awarded to student winners from the 11th and 12th grades. Information, entry materials, and program instructions may be obtained by writing Future Scientists of America, 1201 16th St., N. W., Washington 6, D. C. Reports of student projects are due March 31, 1962.

Job Futures for Girls in Biology

This is the subject of a new pamphlet, issued by the Women's Bureau of the U. S. Department of Labor. It may be obtained from the Superintendent of Documents.

On the Origin of Organic Compounds

DENNIS HARPER and JERRY LEVY,*
Bloom Township High School, Chicago Heights, Illinois

In the beginning God created . . . .
—Genesis.

I

One of the most controversial problems of biology is posed by the question, "how did life arise on earth?" To find an answer biologists have returned in recent years to the old notion of spontaneous generation. They have concluded that life was originally formed from inorganic materials, and that this phenomenon has not occurred since.

In his book, *The Origin of Life*, Oparin suggests that the spontaneous generation of life could have been possible if the oceans had contained large amounts of complex organic materials. These materials would serve not only as structural components but also as energy supplies for the first organisms. The appearance of amino acids from simple inorganic substances undoubtedly marked the initial step in the creation of life.

The purpose of the experiment was to duplicate the possible conditions under which these amino acids could have been formed. The work was based on the assumption that conditions on the primitive earth were favorable for the production of the organic compounds which characterize life as we know it.

II

According to modern theory the origin of life required a reducing atmosphere, one which was devoid of any free oxygen. This reducing atmosphere consisted of methane, ammonia, hydrogen, and water vapor. High energy ultra-violet rays from the sun could easily have penetrated the oxygen-free atmosphere and reacted with the gases, particularly near the surface of the earth; their passage now is largely impeded by high-altitude layers of ozone. Cosmic rays, lightning, and intense heat also could have acted upon these gases, resulting in the synthesis of simple organic compounds such as amino acids and sugars. These were then washed by rain into the oceans to form a sort of organic "soup" of varying concentrations.

The compounds in the primitive ocean could have been concentrated by evaporation; they also could have been subjected to pyrolysis, high pressures, and continued ionizing radiations. The creation of life might possibly have occurred through polymerization and condensation of such organic compounds, which were originally synthesized from the gases under the influence of appropriate energy sources, and all made possible by the sociability of the carbon atom. It is reasonable to suppose that spontaneous generation of the first living organisms might have taken place if large quantities of organic compounds had been present in the oceans of the primitive earth. The process whereby these organic clusters began to carry out life functions in earnest needed to have occurred only once.

The synthesis of amino acids is therefore a first stepping stone in this complicated process. When joined together into long chains by peptide linkages they are appropriately called the "building blocks" of proteins. It is interesting to note that thousands of different proteins may be formed from only twenty-four amino acids, depending on the nature of the side chains involved.

The formation of protoplasm may theoretically be traced by the following general formulas:

nucleotides + nucleotides → nucleic acids
protein + nucleic acids → nucleoprotein
protein + nucleoprotein → protoplasm.

Somewhere between the formation of amino acids and protoplasm, substances called "coacervates" appeared in the primitive seas. These organic compounds in colloidal suspension opened a new phase of chemical evolution that led to the origin of life.

One may speculate that each cluster of such organic particles occupied a definite space, later acquiring a semipermeable membrane. These clusters then began to simulate life functions in a slow and rather clumsy manner. Through the eons they evolved into growing

*These were two students of Mr. Richard Aulie now teaching at Evanston High School, Evanston, Illinois.

and reproducing clusters of organic matter. The first organisms probably were heterotrophic, obtaining their basic constituents from their environment instead of synthesizing them from carbon dioxide and water. Ultimately, a simple heterotrophic organism could develop the ability to synthesize various cell constituents and thereby evolve into an autotrophic organism.

III

An apparatus in which such primitive conditions could be duplicated had to be constructed. The basic design is a modification of a model first described by Miller. Electrodes were installed with ground joints providing relative ease in adjustment of spark gap and removal for cleaning. A mercury dip leg was employed as a rough pressure gauge and safety valve to release accumulation of high pressure. A stop-cock with two openings was also incorporated to prevent oxygen from seeping in while charging the apparatus with the gases.

An electrical discharge of at least 60,000 volts was produced with a high-frequency Tesla coil built for the experiment, using 120 volts A. C. current fed first through a 9,000 volt neon sign transformer, then through a condenser and rotary spark gap. The rotary spark gap, made of ¾ inch plastic disk and heavy tungsten wire electrodes wired in a series on top of the disk, acts as a distributor, giving the condenser time to charge and discharge. The speed of rotation partially determines the frequency of the coil. The transformer, condenser, rotary gap, and primary coil, made of 40 turns of wire on a 2-inch diameter cylinder, constitute the primary circuit. A secondary coil, made of 800 turns of No. 24 wire around a 6-inch diameter cylinder, is placed over the 2-inch cylinder without making any connection with the primary circuit. Thus an electromagnetic field induced high voltages up to approximately 120,000 volts, well over the needed maximum. The Tesla leads are attached to the electrodes on the spark discharge apparatus and the entire apparatus was ready for operation.

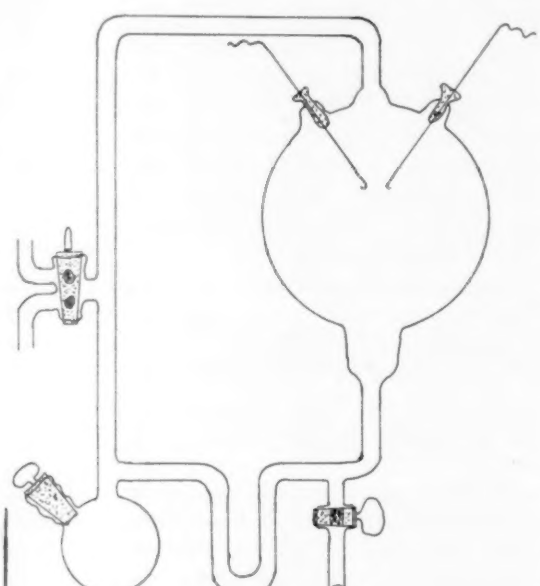

Figure 1. The glass apparatus. Water is boiled in the smaller sphere to promote circulation of steam and gases. The "soup" collects in the u-tube; and the mercury dip-leg, lower right, acts as a safety valve. Adjusting distance between electrodes determines the voltage.

The glass apparatus was first evacuated of all free oxygen with a vacuum pump. Distilled water was added to the evacuated system, which was then charged with 100 mm. hydrogen, 180 mm. ammonia, and 180 mm. methane. A hot plate was used below the 500 ml. flask, and boiling brought steam and gases together in the vicinity of the electrodes. After waiting for ample condensation of moisture on the inside surface of the five liter flask the spark was turned on which then disassociated the gases into ionic fragments as follows:

$CH_4 \rightarrow CH_3, CH_2, CH, C, H$
$NH_3 \rightarrow NH_2, NH, N, H$
$H_2O \rightarrow H, OH, H, H, O$
$H_2 \rightarrow HH, H$

Through polymerization, condensation, oxidation, reduction, and cleavage these fragments were subsequently recombined to form carbon monoxide, carbon dioxide, hydrogen cyanide, formaldehyde, and various amines.

Certain difficulties were encountered during the first run. Heat loss required insulation of glass between the two flasks. Excess pressure built up early in the run even when boiling was stopped; later investigation showed that large amounts of HCN gas were being formed. Eventually a ground joint in the 5-liter flask

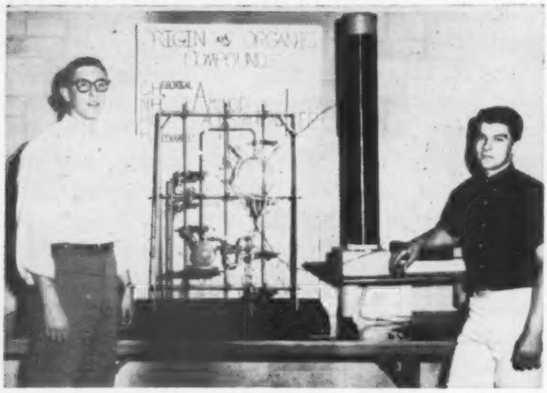

Figure 2. Jerry Levy and Dennis Harper, left and right, standing beside the apparatus in which they successfully synthesized amino acids during their senior year at Bloom Township High School.

popped out and the gases were lost. Preparations were then made for the second run, during which the previous difficulties were eliminated.

The Tesla electrical apparatus broke down several times during both runs. The major trouble was in making a condenser that would hold up under the high voltages during long running periods. The condenser was built of ⅛" plate glass with sheet copper placed between each piece of glass. Several pieces of glass shattered because of heat generated between the copper sheets, due to the weak dialectric constant of the glass. Since break-down of the condenser continued despite numerous precautions, we simply acquired a supply of used glass and replaced each plate immediately on cracking.

IV

After the apparatus was operated for fifty hours the solution was withdrawn and prepared for chromatographic analysis. By this method, separation and identification of the soluble amino acids present in trace amounts in the apparatus is possible, thus establishing the success of the experiment. The technique is dependent on the principle of "differential absorption" by which molecules migrate at different speeds through appropriate media according to their molecular weights.

The end of a strip of filter paper is impregnated with a few drops of organic solution containing unknown amino acids withdrawn from the 500 ml. flask. This strip is then placed in a test tube with the bottom of the paper dipping into ligroin-treated phenol. The amino acids and phenol rise through the paper by capillary action. The different distances they migrate are partially dependent on their molecular weights.

Migration requires about three hours. Acetone to promote rapid drying is then sprayed over the filter paper as it is withdrawn from the test tube. The filter paper is then sprayed with ethyl alcohol solutions of s-collidine-ninhydrin and pyridine-ninhydrin. The resulting colors are diagnostic for the particular amino acids in the apparatus. The positive test thus constitutes proof that synthesis of amino acids actually had occurred.

The prussian blue test is used for the presence of HCN gas. A few drops of the organic soup were added to a mixture of ferric chloride and ferrous sulfide, with a bright blue-green color constituting a positive test for HCN. The test for aldehydes is important in determining the success of the experiment. Silver nitrate is titrated with ammonium hydroxide. Upon the addition of a known such as dextrose, which carries the aldehyde group, the solution "mirrors out" in the form of a silver layer adhering to the inner side of the test-tube, thus providing a control. When organic soup was added to the titrated mixture in place of the known dextrose a heavy concentration of silver settled to the bottom. This test was considered fairly successful, even though the presence of HCN in solution prohibited completion of the silver coating.

Amino acids could not be detected in the first run of nine hours, due to their low molecular concentrations. The second run was continued to forty hours until no appreciable trace of NH_3 remained in the system, indicating that production of amino acids had ceased.

Further experiments are being planned which will include (1) a much longer, third run, following the general procedures of the first two but with the initial concentration of hydrogen reduced considerably; and, (2) a fourth run with certain catalytic reagents added to a gaseous mixture such as that used in run three, such as silicates, phosphorous, calcium, and oxides. The yields from these runs will be analyzed by the following methods: (1) paper chromatography, (2) gas chromatography, (3) electrophoresis, (4)

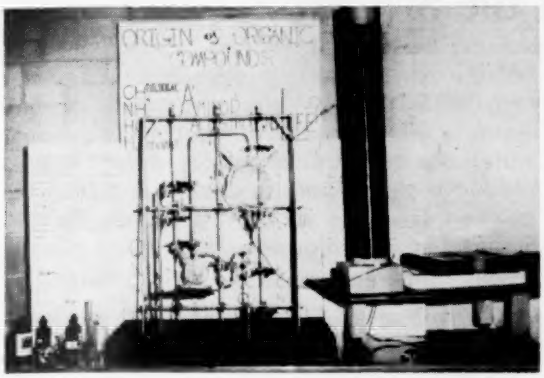

Figure 3. The complete apparatus as it appeared during the experiment. Condenser and upright Tesla coil are connected with the electrodes that project into the larger glass sphere.

spectrophotometry, and (5) other chemical tests.

V

Electrical discharges in a mixture of ammonia, methane, hydrogen, and steam produce amino acids and other organic compounds essential for life. This mixture has been suggested as composing the atmosphere during the formation of the early earth. It can be concluded from this experiment that the conditions in the primitive atmosphere thus described were the most favorable for the production of the first organic materials. This synthesis of amino acids in the early atmosphere is therefore tentatively suggested as the basis for the later evolution of life on earth.

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Acknowledgments

We are grateful to Dr. Stanley L. Miller of University of California at LaJolla for valuable advice and encouragement through letters and a personal conversation; to Mr. Robert van Nordstrand and Mr. John Glover of Sinclair Research Laboratories, Harvey, Illinois, for helpful interest during the course of this study; and to Mr. Richard Aulie, teachers at Bloom Township High School, Chicago Heights, Illinois for sponsoring us.

Scientists Complete 65-Day Trek to South Pole

An eight-man scientific traverse party has just completed a 65-day trek through many Antarctic regions never before explored. The journey was more than 1200 miles in length, and originated at McMurdo Sound December 10. The scientists made measurements to determine the elevation and thickness of the ice cap and the nature of the subglacial rock surface. Ice in some areas is about two miles deep, and analysis of ice cores by this group can give valuable information on the past history of the ice and past climatic conditions in Antarctica. Scientific information collected on the trip will require many months of careful analysis, and will be studied in relationship to the data taken by other Antarctic scientists in this and past years.

Living Insects and Mites Found on High Antarctic Plateau

Living insects and mites have been found at an elevation of 6,000 feet above sea level, 90 miles from McMurdo Sound, Antarctica. This is believed to be the highest altitude at which insect life has ever been encountered on this frigid, ice-covered continent.

The organisms were found by Keith A. J. Wise, a New Zealander. The work is supported by a $32,039 grant from the National Science Foundation through its U. S. Antarctic Research Program (USARP).

The Cycle of Nature in the Spaceship Cabin*

VASSILY PARIN
Member, USSR Academy of Sciences

The exploration of the solar system may be arbitrarily divided into three stages. The first stage is a reconnaissance of the earth's outskirts by means of instruments. The second stage is a study into the effect of space, zero gravity, and acceleration loads during the take-off and re-entry on the living organism. In this stage, emphasis is placed on the development of systems which make space flight and re-entry completely safe. The third and final stage will be manned space flight.

We are in the second stage and on the threshold of the third one.

I would like to stress that I do not minimize the services rendered by the dogs Belka and Strelka. But the earth's other inhabitants on board the ship were of no less importance to science. The scientists had tried, successfully, to place an "abridged edition" of the earth's animal and vegetable kingdoms in the container.

The container also carried ampules with desoxyribonucleic acid, or DNA as biologists dubbed it for short. This is a high-molecular compound, very near to animal proteins in its properties. DNA is an indespensable component of cellular nuclei. In recent years DNA had been synthetized *in vitro*, in a test-tube, and as has been established, DNA plays a vital role in the transfer of hereditary features from generation to generation. Of course, it is essential for us to know how DNA reacts to space influence.

Test-tubes holding bacteriophages, the simplest of all living beings, were placed in the container side by side with cultures of more highly organized microbes, such as enteric bacilli, staphylococci, and actinomyces, or ray fungi, which produce antibiotics. The other envoys to space were insects and small mammals, such as mice and rats. In this way, we are in a position to judge how space factors affect animals standing on various stages of the evolutionary ladder. We can watch not only a direct effect of, say, cosmic rays on the blood-producing system, the marrow, of mice, or on the higher nervous activity of rats, but also trace more remote results of this effect on their descendants.

The subjects of the experiment had been selected so as to meet the above tasks. Biologists had studied *Drosophila*, a genus of fruit fly, for years. As they put it, Drosophilae are very plastic. In other words, every subsequent generation of these flies quickly responds to the environmental influences affecting their descendants. Mice quickly reach puberty and are very prolific. Therefore, a few generations of insects and rodents may give an early answer to the question of how space affects living creatures.

Apart from studies into what may be called short-run problems, that is, matters relating to manned earth satellites, we probed "long-run" problems in our experiment. At first, it appears, man will fly orbital spaceships or observatories traveling outside the terrestrial atmosphere. Next will be flights to the moon and only then to Mars and Venus. The water and food stocked on board manned spaceships will be sufficient for trips near and around the earth, while the oxygen required for breathing will be replenished by carbon dioxide reduction. Trips to Mars and Venus, however, may last for months. Another approach has, therefore, to be taken to the problem of oxygen, water, and food supply on interplanetary flights. The long-range spaceship should become a closed system where the substances go through a complete cycle.

Man and animals consume oxygen in breathing and give out carbon dioxide which is the final product of gas exchange. Plants, on the other hand, absorb carbon dioxide which is essential for photosynthesis and produce oxygen.

The most economical way to restore the normal composition of air is to utilize the photosynthesis of higher plants. The algae, *Chlorella*, is of special interest in this respect.

*This is being printed so that interested readers might read first-hand a Soviet account of some biological research on space travel. Received from the Embassy, U.S.S.R., Washington, D.C.

It easily propagates, is robust, and, what is most important, reduces the largest possible amount of free oxygen from carbon dioxide. Indeed, the plant is able to supply a sufficient amount of oxygen in the cabin of a spaceship. There is a body of opinion among my colleagues that the quickly-growing *Chlorella* can at the same time be utilized as food, though no final conclusion has been derived on that score yet. The experiment with *Chlorella* is the first in the research program involving the rotation of substances in an artificially closed system.

In building long-range spaceships, scientists will have to deal with what once faced the Biblical Lord of Sabaoth. But they will "create" their microworld according to a plan, taking accurate stock of all factors. Of course, this is a matter of the future, probably, not so remote, but nevertheless, in the future. All the same, we must not sit idle. We ought—right now—to carry on purposeful studies which will bring us closer to man's coveted goal—the exploration of remote worlds.

Tracing the Origin of Life

A. VOLOGDIN
Corresponding Member, U. S. S. R. Academy of Sciences

The origin and development of life on our planet are questions of paramount importance, the study of which has a direct bearing on our understanding of the world we live in and of its history.

In our endeavor to explain the origin of life we may rely on the comprehensive scientific hypothesis of Academician A. I. Oparin which in its biochemical part merits recognition as a theory.

But up until recently we were unable to trace the "roots of life." Paleontology has accumulated a wealth of materials on the development of life but only to a period of not more than 570 million years. "The roots of life" certainly go much deeper. For 570 million years ago life in the seas was already represented by many groups of comparatively highly developed animals and plants—worms, crustaceans, multi-cell red and blue-green algae. But where the sources of life lie remains a mystery.

Several sciences, such as geology, geochemistry, and stratigraphy, have had to attain a high level of development to help paleontology delve into more ancient times. Thanks to the joint efforts of geologists, petrographers, geochemists, and stratigraphers it was established that the earth crust with its oceans formed 3,500 to 4,600 million years ago. Since the evolution of life on earth proceeded ever faster as time went by, there is every reason to believe that life originated very much earlier than is assumed. But when?

Modern microscopy makes it possible to establish that very fine preparations from ancient sedimentary rocks contain quite a few remnants of bacteria and some doubtful formations which could be living organisms—possibly plants.

The primary atmosphere and hydrosphere differed strongly from what they are today. Most likely they contained methane, ammonia, and free hydrogen, while oxygen and nitrogen were probably absent. The atmosphere contained also much water vapor, carbon dioxide, sulfur dioxide, chlorine, helium, and argon. It was probably much thicker than now. According to the latest findings of microbiologists, bacteria could well sustain in the primary atmosphere and take an active part in the formation of rocks.

There are groups of bacteria capable of surviving only on hydrogen and some simple carbon compounds. Some groups of bacteria can thrive on the decomposition of hydrocarbon gases. Some microorganisms are able to live thanks to the energy released by the transformation of ammonia, sulfur, iron, etc.

The successes of modern paleontology enable us to consider that such anaerobic bacteria appeared 3,500 to 4,600 million years ago, i.e., soon after the formation of the earth crust. Furthermore, these microorganisms changed the composition of the atmosphere, but not only the atmosphere, paving the way, as it were, for the future blossoming out of life.

The last proposition needs to be explained. There exist bacteria capable of splitting up sulfates (gypsum, for instance), with the subsequent formation of hydrogen sulfide. After this, sulfur was reduced from this hydrogen sulfide. In this way many deposits of this element formed at various geological periods.

Some bacteria precipitate limy silt which later on went on to form limes, marbles, dolomites, marls, and some other sedimentary rocks.

Academician V. I. Vernadsky was the first to express the supposition that nitrogen and oxygen are secondary biogenic gases. They appeared in the atmosphere thanks to the activity of certain groups of microorganisms. By decomposing primary compounds these bacteria satiated the air with nitrogen. Nitrogen compounds provided these bacteria with the energy needed for their life.

As for oxygen of the atmosphere, it was created not so much by bacteria as by algae which filled the atmosphere with oxygen in the process of breaking up carbon dioxide with the help of sunlight.

Only after microorganisms and algae had done the job of creating a suitable atmosphere did it become possible for life to start developing vigorously. Thus, it was microbes and algae that were the "sculptors" of our planet.

It is beyond doubt now that bacterial life existed on earth as early or more than 3,000 million years ago. Algae appeared a little later on; their oldest remnants date back 1,500 to 2,000-odd million years ago. Some carbonate rocks of this age have retained traces of fine cellular structure. The deciphering of these structures has even made it possible to single out species, genera, and families of blue-green and red algae. The number of these organisms is amazing. In this connection it should be stressed that giant accumulations of red and blue-green algae in primeval seas were their own killers. Paradoxically, but that was so. The algae changed the environment of habitation. These changes stimulated the development of some forms of organisms while resulting in the destruction of those failing to adapt themselves to the new environment.

But even now much of what is connected with the dawn of life on earth remains unknown. Much effort still has to be done to trace the history of life hidden beyond the vistas of time.

"Century 21 Exposition"

The NSTA will develop and supervise a series of "do-it-yourself" exhibits designed to introduce science concepts to children between the ages of 9 and 13 under the coordination of Robert F. Rice, head of the science department at Berkeley, California, High School. The plans call for approximately 30 scientific exhibits where students may perform experiments and observe biological developments. The "Century 21 Exposition" will open in Seattle, Washington, April 22, 1962, and will close October 22, 1962.

Food Additives

A new reference handbook has been prepared by the Manufacturing Chemists' Association, Inc., 1825 Connecticut Avenue, N. W., Washington 9, D. C. It is a basic reference book which contains quite a bit of interesting material pertinent to biology teachers on food additives. It may be obtained by writing the above address.

Sierra Science Journal

Sierra High School, Whittier, California, has published a report of the projects, mostly biological, of the members of its Science Club. It is illustrated and most attractively done. Copies may be obtained from Mr. Sol Taylor of the above school. Congratulations.

Biochemistry

The American Chemical Society, 1155 16th Street N. W., Washington 6, D. C., has announced the publication of a new journal, "Biochemistry," to be issued six times per year. Further information may be obtained by writing the ACS.

Fact

There are between 36 and 37 million people in this country between the ages of 45 and 65, and an additional 16 million over 65.

Homeostasis and Kidney Functions*

RANDOLPH R. BROWN, *Niskayuna High School, Niskayuna, New York*

If there is one uniquely biological concept, it is, of course, evolution—evolution adorned in the trappings of speciation, genetics, and now, biochemistry. Evolution is, or should be, central to every biological concept. It is the warp and woof of biology, and quite properly, too.

It is not my intention to eulogize this concept, nor is it within my power to dignify it by so doing. Neither shall I resurrect its interesting embryology. I mention evolution now because evolution is a fact, a fact in which the kidney has played an important part. In discussing the kidney it is rather too easy to get involved in loops, and tubules, and clearing ratios, and the danger of so doing lies in missing the point completely. For the wonder of the kidney is not in its marvelous complexity; nor, as others would have it, in its marvelous simplicity; nor in its size; nor its position; nor in its interesting connections. The wonder of the kidney is in its past.

Now in discussing the past of the kidney, its evolution, it is difficult not to be teleological. It has long been pointed out that *purpose* makes good theology, but poor science. And this is good sense. I think we all subscribe to such sentiments. Orthogenesis is not respectable biology. There is no goal, no summit, no end to evolution. There is in evolution no fulfillment.

Except one.

And that is survival. And if there are two, the second is homeostasis. For these words—survival, homeostasis—are nearly synonyms, if not according to Webster then according to the evolutionary record.

Let me make myself clear. Evolution is a process by which living things change. If such change is compatible with simultaneous or subsequent environmental change, the result is survival. If not, extinction. Now, homeostasis implies a changing environment. Without environmental fluctuations and changes, the concept of homeostasis ceases to exist. Hence to portray homeostasis as a goal of evolution is simply to portray as a goal a system that provides the greatest stability in a changing environment. It is, in its own way, a road to the future. A road to survival.

Homeostasis is not the only road. There are others. But homeostasis is the best road. Its development has not been direct and has not been without cost, but homeostasis is worth the price of many failures.

In order to appreciate the value of homeostatic tranquility and the advantages that homeostats derive from this condition, we should take note of some rather curious facts of life.

1. Life, whatever that is, is restricted. It can flourish in only very circumscribed conditions.

2. Life exists within an extremely narrow range of temperatures among those available in the solar system.

3. Life demands an oddly heterogeneous supply of elements and minerals, the importances of which are in no way commensurate with their respective abundances.

4. Life demands these materials in peculiar ratios exactly.

5. Life demands exposure to electromagnetic radiations of very specific characters.

The advantages that homeostats enjoy derive exactly from the stringency of these requirements. The conditions which will allow life to exist, much less prosper, are by no means everywhere available, so that living things must either be restricted to a few favored localities or else reduce their dependence on, or free themselves from, the restricting conditions described above. The paradox, of course, is that living things are not restricted to a few favored localities and have not freed themselves from their restrictions. They have escaped but are not free.

The freedom that living things appear to enjoy is not really freedom. Rather it is a different kind of imprisonment. Rather than being imprisoned in the few favored natural localities amenable to life, living things have become imprisoned within themselves. They have shut themselves in. They have built

*This paper was presented at the NABT meetings with the AAAS in New York, December, 1960.

themselves capsules, stocked the capsules with materials with which to sustain themselves—elements all in the right proportions and that sort of thing—and have climbed in and sealed the door. Enclosed in their new capsules, isolated from the rigors of inclement environments, living things have conquered the earth.

But not without troubles. Not a bit. In retreating—or advancing if you like—to a capsular existence, certain problems arise. The enclosed environment may become changed in several ways. It can be changed by the depleting activities of life, which extract materials from the capsular stores, and it can be changed by the contaminating activities of life, by its own metabolism. Hence the capsular environment becomes less and less fit for life and must soon cease completely being amenable to life unless new materials can be brought in from the outside to counteract the depletions, or unless processes of excretion can alter or remove the contaminating substances.

It is this process of taking in, altering, and excreting that brings about the condition known as homeostasis and the refinements of which I consider to be the goals of all evolutionary mechanisms. It should be noted here—and I wish to draw special attention to this point, for it is one which does not ordinarily command much attention—that because the homeostatic mechanisms have not reached perfection, because they are still subject to mechanical failure, a premium is placed on processes which can replace unfit, damaged, contaminated capsules. It is this replacement which we more commonly call reproduction and which evolutionists commonly cite as a desirable and effective means of survival. Survival by high reproduction, however, has always seemed to me to be an unsatisfactory solution to the survival problem. Effective, yes, but not really part of the game. It is to me a sort of evolutionary deception, an end-run. Homeostasis is still the real key to evolutionary success.

If these remarks seem inappropriately long for an introduction, let me attempt a justification by pointing out that the concept of homeostasis is mentioned by name in only one out of six secondary school textbooks I examined recently, and not one author considered the topic of sufficient importance to devote a chapter or even part of a chapter to it. The idea of self-regulation is an adopted child in secondary school texts. Never is it given space for its own value. Invariably it is pushed reluctantly onto the stage amid such splendors as *How the Lungs Work; Kidneys, Organs of Excretion; The Work of the Blood; Our Endocrine Glands.* Not one book mentions the peculiar thermal properties of water and its exquisite solvent properties that make water a uniquely suitable medium within our life capsules.

It is my custom in teaching to consider self-regulation as a phenomenon apart, worthy of study in its own right.

The experimental approach that I would like to present to you now normally takes the form of a demonstration, though I have used it in the past as a laboratory exercise for a small group of Advanced Placement students to do themselves.

Two aspects of homeostasis lend themselves well to experimental treatment. The first is the relationship between energy consumption and temperature regulation. This can be demonstrated easily with a manometer attached via tubing to jars containing mice or frogs. If sodium hydroxide is put into the jars as a carbon dioxide absorber, the rate of oxygen consumption can be measured at different temperatures. The profound changes in the behavior of the frog as the temperature fluctuates widely is testimony for the value of temperature regulation in the mouse. Since this exercise is so common in college physiology courses, however, I don't intend to do more than mention it here.

Instead I would like to devote my attention and yours to the second aspect of the problem of maintaining a constant salt balance within living capsules—or bodies, if you wish—and especially to the consequences resulting from faulty regulation.

It is to show the necessity for such regulation that the following demonstration is designed. Its conception is not original. I am indebted to Dr. William Harvey, physiologist, for introducing it to me. Dr. Harvey is a research fellow at Harvard University and is not to be confused with another man of the same name having only *historical* interest.

I find it effective to present the demonstra-

tion as a laboratory exercise. I require my students to note what is done, what happens, and to write it all up in a laboratory report with appropriate conclusions. I also find it effective as a method for introducing the idea of homeostasis and consequently do not preface the demonstration with any remarks of such a nature.

The demonstration itself can be done in three parts, an introductory demonstration, a quantitative follow-up, and a summary demonstration. It is usually not possible to do these in less than three periods. The introductory demonstration is done as follows:

To 10 ml. of distilled water in a graduated hematocrit tube are added 10 drops of whole citrated blood. Similarly 10 drops of blood are added to 10 ml. of salt water (salty enough to taste easily), and both tubes are gently shaken and allowed to stand for a minute or two. These two tubes are then centrifuged for a few minutes and removed for examination.

When they are examined, it is seen that one is homogeneously red throughout and the other is clear, except for a pellet of blood cells at the bottom. The red tube is the one which was filled originally with distilled water; note that it has no pellet of blood at the bottom.

These are the data for students to record under the heading, "Observations and Results." Their next problem is to draw conclusions and explain these curious results. Most will find doing so difficult.

Eventually with luck one or two students will discover the osmotic relationships involved. The discussion of these relationships will lead us to discuss the meaning and significance of hemolysis. In so doing, of course, one wants to place considerable emphasis on the environment which surrounds red blood cells, the changes that we have brought about in this environment, and the consequences of such manipulation. The internal environment of our life capsule, of our homeostat, our mammal, now begins to take on meaning.

You are probably aware that we have demonstrated the consequences of two extreme conditions, distilled water and quite salty water. What are the consequences of altering the salt concentration only a little? What is the average salt concentration of blood plasma? It would be better to speak of the osmolarity of the plasma since substances other than salt contribute to the total osmotic pressure. These are questions the students ask.

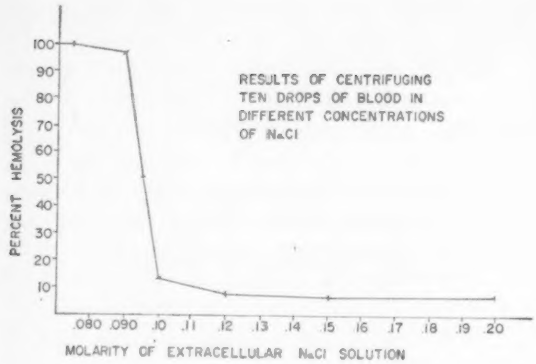
To answer, we can prepare tubes of sodium chloride solutions of increasing concentrations, add equal amounts of whole blood to each and centrifuge as before. In practice it is convenient to use concentrations of 0.20M, 0.15M, 0.12M, 0.10M, 0.095M, 0.090M, 0.085M and 0.080M.[1]

While these are centrifuging, we must prepare some sort of measuring device for determining the amount of hemolysis that will occur. If we assume that 100% hemolysis is achieved in distilled water, then we can express other results as some fraction of 100%. That is to say, if equal amounts of blood and water are used, a tube in which 50% of the cells have hemolyzed should be just half as red as a tube in which 100% of the cells have hemolyzed. The color scale we want can thus be made by preparing serial dilutions of the mixture of blood and distilled water. A 1:1 dilution should give us the color equivalent of 50% hemolysis, a 1:1 dilution of this solution should give us the color equivalent of 25% hemolysis, a 1:1 dilution of this should give us the color equivalent of 12.5%, and so on until we have color standards for 6.25% and so on.

We have only to compare our centrifuged samples to our color standards to determine the percent hemolysis that has occurred in each tube. If red color shows up in the supernatant liquid, that liquid must be hypotonic to the red blood cells. If the pellet of red cells at the bottom of the tube is abnormally shrunken and small, that tube must contain a solution that is hypertonic to the red cells. The isotonic solution will be that in which the pellet is found to be of maximum size and which is at the same time colorless. In actuality, the isotonic solution is not colorless, inasmuch as the rough handling of the red blood cells leads to some mechanical cellular breakage.

To verify our determination of the isotonic concentration, we need only centrifuge 10

[1]In grams percent: 1.14; .855; .684; .570; .542; .513; .485; .456, respectively.



drops of blood in 10 ml. of blood plasma and compare the results to the experimentally determined isotonic solution.

When these data are all collated and graphed, the pattern of the curve is astonishing. See Figure 1. The slope of the curve should be convincing evidence to anyone that precise regulation of our blood salt concentration is an absolute prerequisite to survival. Small changes toward the hypotonic bring about hemolysis and the consequent danger of crystallization of hemoglobin in the kidneys, while small changes toward the hypertonic bring about shrinkage of the red cells and consequent disturbance of oxygen transport (anemia).

The role that the kidney plays can partially be determined in a summary demonstration in which 10 drops of blood are centrifuged in plasma and the result compared to 10 drops of blood centrifuged in urine. The observed increase in osmolarity of urine over plasma must be due in part to the excretion of excess salt taken in with food, in addition of course, to the excretion of the toxic end-products of our metabolism. A microscopic examination of blood cells in plasma, and blood cells in urine, should confirm the conclusions we have drawn above.

A careful and thoughtful analysis of the graph in Figure 1 should make us wonder that we should survive at all. It begins to look as though the homeostatic mechanism that insures our survival is rather better suited to bring about our extinction. There is no doubt but that our lives hang by a thread, or rather by a grain or two of salt. But if our precarious existence seems to us like an unnecessarily risky state of affairs, we can take comfort from the fact that there is no alternative. It is the price we have to pay in order to emigrate from those primitive sanctuaries in the oceans millions of years ago. Life is still the delicate thing it was in eons past and could not leave the shelter of oceanic stability unless it were to find that same stability elsewhere.

This demand, this selective pressure to find stability, has been so dominant in the evolution of life, that living things have encapsulated themselves, trapped themselves in their microcosmal oceans and made themselves their own victims of evolutionary gadgetry, like kidneys, victims rather of the consequences of the mechanical failures that inevitably accompany such dependence.

We can take heart, however, for in becoming dependent on an evolutionary gadget like the kidney, we have gained a sort of independence, an independence that has, after all, given us the world.

The moral of this peculiar story, if there is one, is not that we enjoy the free life precariously, not that we are perched on the precipice of a grain of salt. The wonder is not that we are living dangerously, but that we are living, that the problem of homeostasis has, after a fashion, been solved. And if the solution is in some measure unsatisfactory and imperfect, let us not be surprised, for it is, after all, only what we could expect from a game of chance.

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Writing Articles for Publication

JOHN BREUKELMAN, *State Teachers College, Emporia, Kansas*

Throughout the period of eleven years during which I served as Editor-In-Chief of *The American Biology Teacher*, many manuscripts of excellent content came to my desk, only to be returned immediately to their writers. In spite of excellent content, these manuscripts required such extensive revision before going to the printer that the writers in many cases had to start all over. I received manuscripts written in longhand, in single spaced typing, typed on both sides of thin paper, typed with margins too narrow for the printer's instructions to be added, and with references so sketchily made as to defy indentification. In many cases no title was indicated, and in two instances the writer did not even give his name and address.

It is hoped that this article, which is the third of a series (Breukelman 1943, 1949), may have some information which will enable a person who has an idea worth sharing to present the idea in acceptable publication form. This means that the manuscript when submitted to the editor will be practically ready for him to add the printer's directions. Carefully written manscripts have better chance of acceptance than those that are poorly done, and are often published more promptly.

The following brief discussion applies particularly to manscripts intended for *The American Biology Teacher*, but the procedures of scientific writing are more or less standard. The "official" guide for biological journals is *Style Manual for Biological Journals*, recently completed by a committee of editors working under the auspices of the American Institute of Biological Sciences. This 92-page manual includes a wealth of information on both writing and preparation of copy. It has been adopted, in whole or in part, by nearly 60 biological journals, including *The American Biology Teacher*. It may be obtained for $3.00 from the American Institute of Biological Sciences, 2000 P Street NW, Washington 6, D. C.

The manuscript should be typewritten, double spaced, on one side only of a standard weight white paper, 8¼ x 11 inch size, with margins of at least an inch on all sides. The writer should keep a carbon copy for reference and as insurance against loss in transit of the original.

The title should be placed at the head of the first page of the manscript, at least an inch below the top of the page. It should be short, but still indicate the content of the paper as accurately as possible. The wording of a title is often a compromise between brevity and accuracy. In the case of longer articles (about 1200 words or more) the author's name is placed below the title, then his school or other professional connection, followed by the city and state. In the case of shorter articles, news items, reports, editorials, or reviews, the author's name, professional connection, and address may be placed at the end of the manuscript.

Subheadings are centered if they are all of equal rank; if there are primary and secondary headings, the primary ones are placed at the extreme left, the secondary ones indented 5 spaces, those of the third order 10 spaces, and so on.

Wording, grammar, and punctuation should be checked several times. It is well to have the entire article, both the rough draft and the finished form, read by several qualified persons. Words that are to be CAPITALIZED in the printed article should be capitalized in

FIGURE 1. A plain white background is effective in bringing out details of a dark-colored specimen, as in this photograph of a chimney swift.

FIGURE 2. The left picture shows more features of the whole plants; the right one shows more details of flower structure.

the copy; words to appear in *italics* should be underlined in the copy; those to appear in **bold face** should be underlined with a wavy line.

Consistency is important; do not write "vigor" in one place and "vigour" in another, or "Amoeba" in one place and "ameba" somewhere else in the same article unless different meanings are intended. Abbreviations should be double-checked. For example, THE NATIONAL ASSOCIATION OF BIOLOGY TEACHERS has been abbreviated both as NABT and N. A. B. T., but should not appear both ways in the same paper. And please, only one of these in the same article: cc, C. C., cu., cm., ml.

References are listed in various ways. In journals of the biological sciences they are usually placed at the end of the article, arranged alphabetically by the author's surnames; in case no author is given, the title is placed in the alphabetical sequence. The exact form of citation varies. For journal articles, the following form, first used by the Ecological Society of America, is becoming more and more common:

Bullington, Robert A., 1958, Teaching ecology in high school biology, Am. Biol. Teacher, 20 (5) 163-165.

For books, pamphlets and other references the following are suggested:

Palmer, E. Laurence. 1957. Fieldbook of

FIGURE 3. The objectives of this picture were to show: 1) a typical nest of the marsh hawk, 2) eggs, and young of different sizes, in the same nest, and 3) appearance of the downy young.

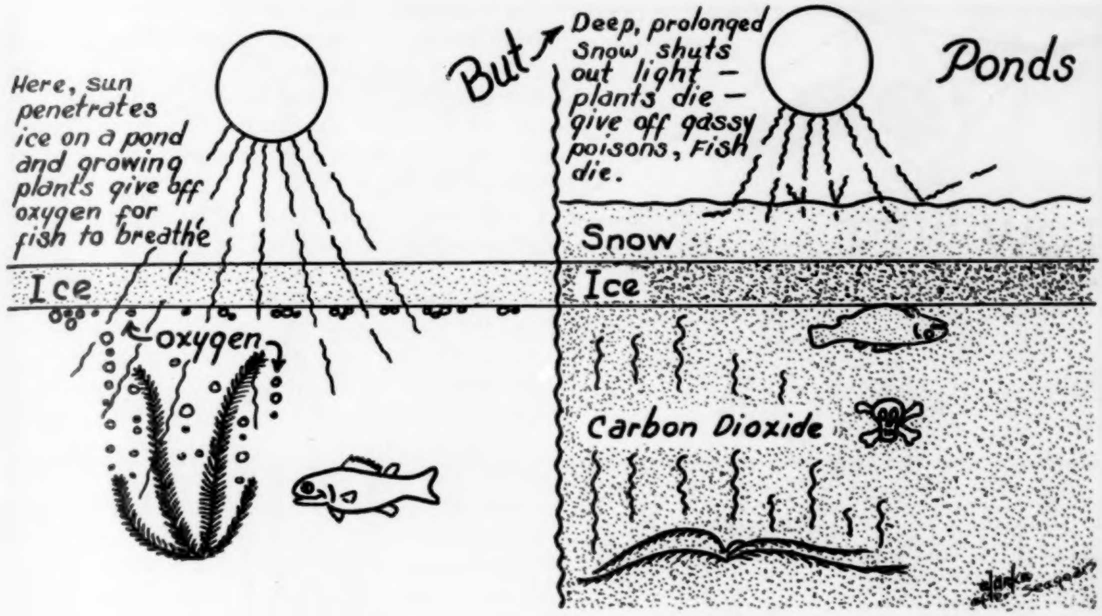

FIGURE 4. Sometimes a fairly complicated story can be told by combining relatively few words with simple sketches.

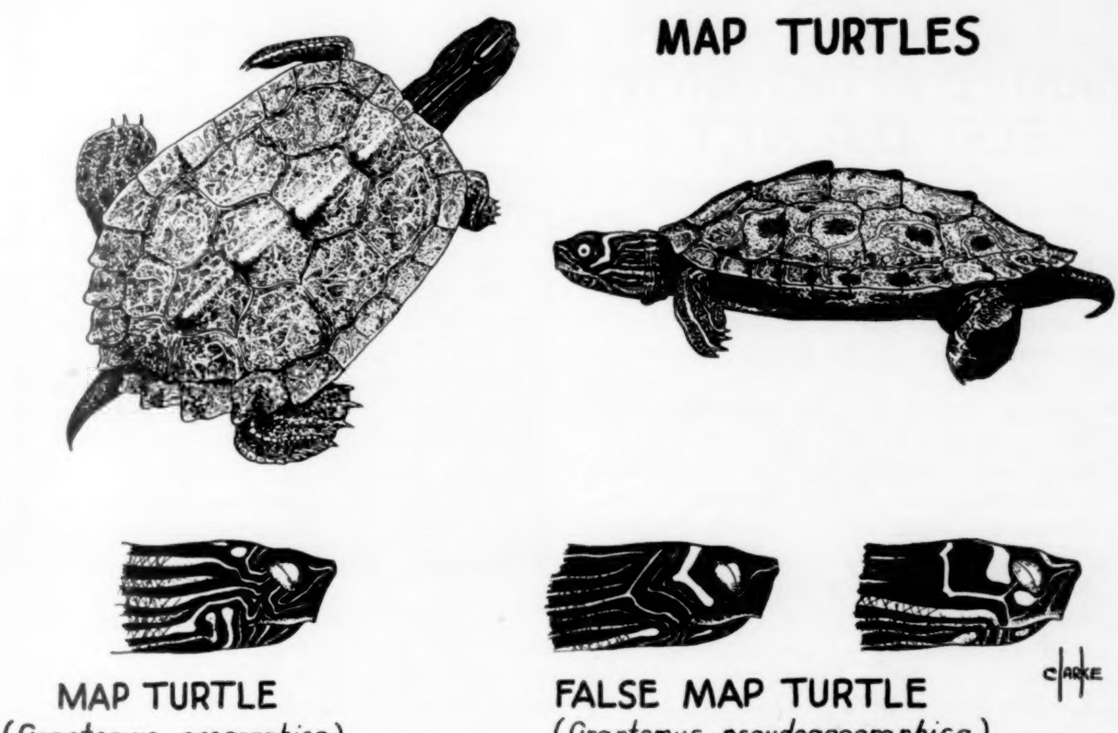

FIGURE 5. Pictures intended for identification or taxonomy must be drawn by a capable artist.

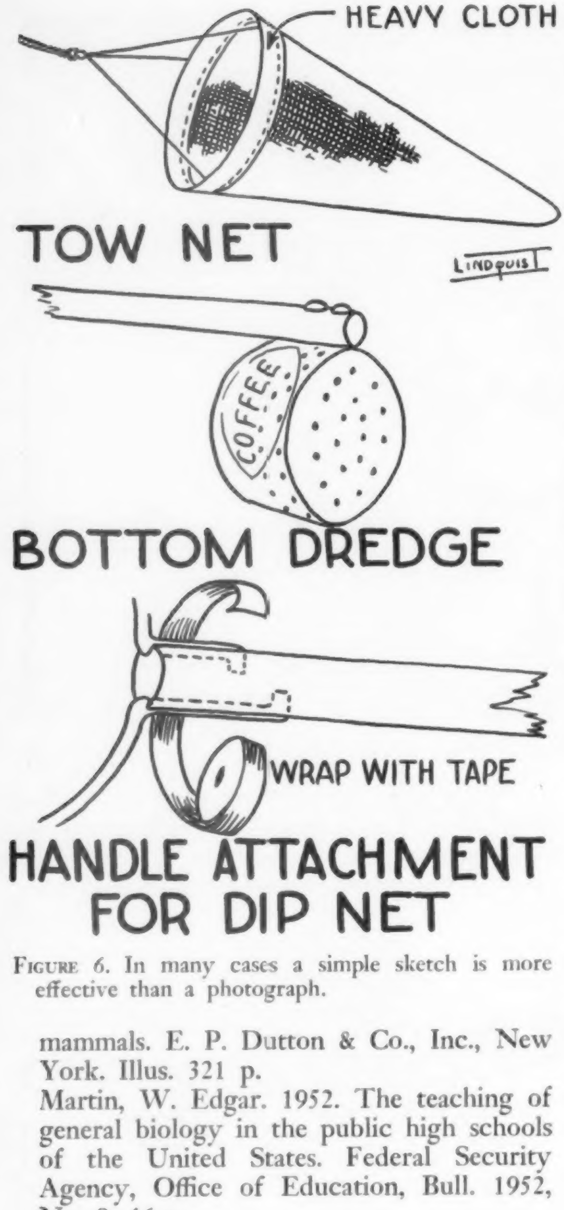

FIGURE 6. In many cases a simple sketch is more effective than a photograph.

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Martin, W. Edgar. 1952. The teaching of general biology in the public high schools of the United States. Federal Security Agency, Office of Education, Bull. 1952, No. 9. 46 p.

Suggested Activities for the Teaching of Conservation of Natural Resources. 1956. Montana Conservation Council, Reporter Printing and Supply Co., Billings, Mont. 47 p.

An Outline for Teaching Conservation in High Schools. 1952. U. S. Department of Agriculture, Soil Conservation Service PA-201. Washington, D. C. 21 p.

When a reference is cited in the text of an article, the surname of the author and the date of the publication are placed in parentheses, for example, (Doe, 1958); if this author has been mentioned before, only the date need be placed in parentheses, for example, "this was the first demonstrated by Doe (1958)." The use of footnotes for such citation has almost disappeared from the current literature of biology.

All literature referred to in the text of an article must be included in the list of references, but general references may be included in the list even though they have not been cited in the article. Thus in the present article, books dealing with the subject of writing for publication are listed even though they are not individually cited anywhere in the article.

The title for the reference list should indicate the type of list. "Bibliography" should ordinarily be avoided, since this term implies an exhaustive list and is also used for card files and other forms of references sources. If each item has been cited in the text of the article "Literature Cited" should be used. If not, "References" or "Selected References" is nearly always appropriate.

In case the topic discussed is seasonal, the manuscript must be submitted to the editor in plenty of time. For example, manuscripts for *The American Biology Teacher* are sent to the printer nearly two months before issue. They should be in the editor's hands several weeks before this, to allow for correspondence, and to give him time to plan the placing of the article in the issue in which it is to appear. Thus an article dealing with a Christmas subject, which should preferably appear in the November issue, will probably be sent to the printer in September. Such a paper should be received by the editor well before the first of September.

Many articles are improved by one or more illustrations; for some articles illustrations are essential. These may be either photographs or drawings. Since the publications of illustrations is relatively expensive, they should be selected with care, so as to illustrate specific points and to fit well into the topic under discussion.

Photographs must be clear, of relatively high contrast and glossy finish, and of such size and arrangement as to tell the desired story. Some contrast is lost in the process of making engravings from photographs (the half-tone process); one should not submit any pictures that lack clearness and detail in either

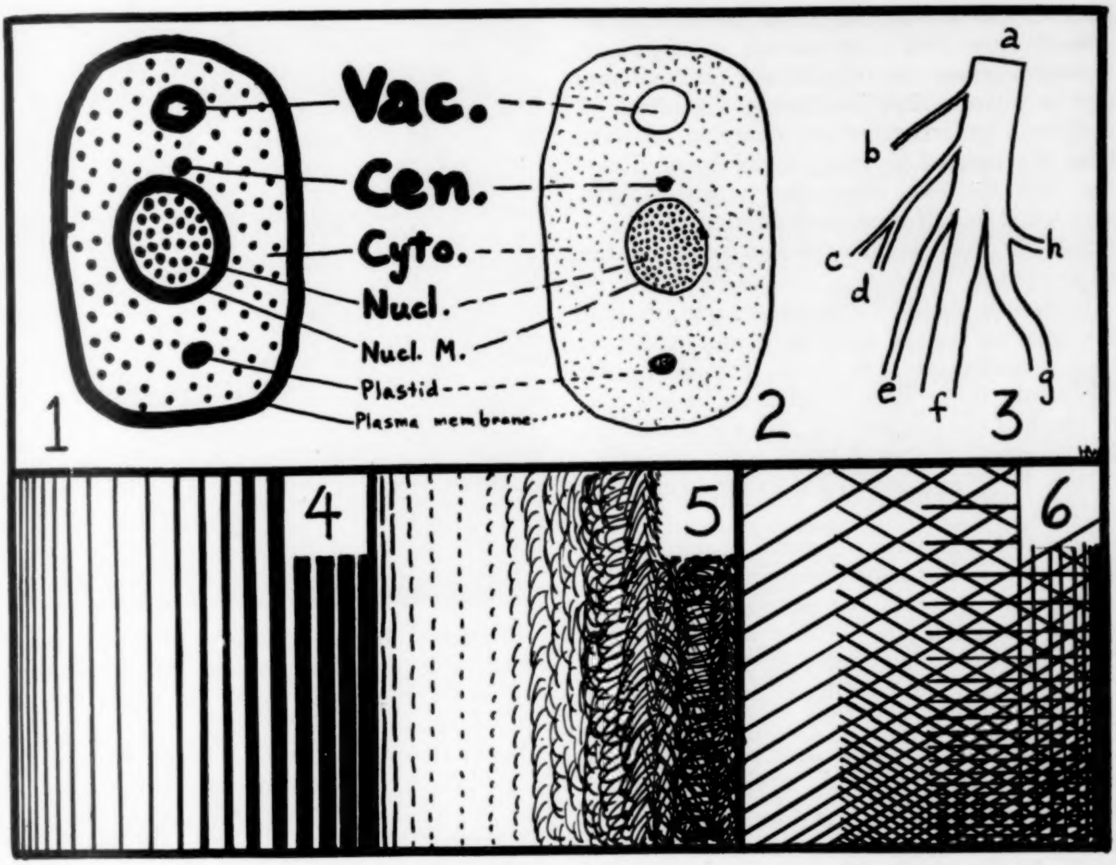

FIGURE 7. Drawing printed only slightly smaller than drawn, with all irregularities appearing as drawn.

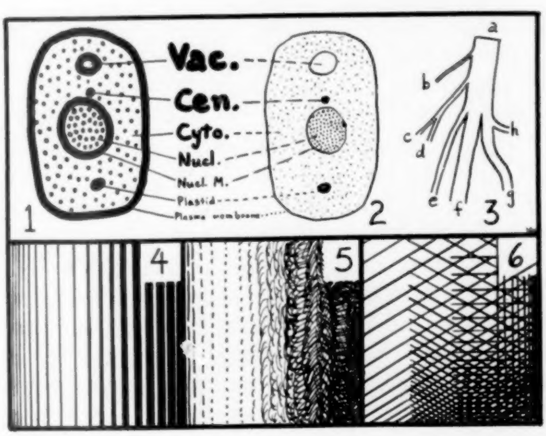

FIGURE 8. Reduced to half size; note smoothing out of irregularities.

the lightest or the darkest portions of the significant area. If the shadows are completely black or the highlights completely white, the picture will not make a good reproduction. The accompanying half-tone reproductions of

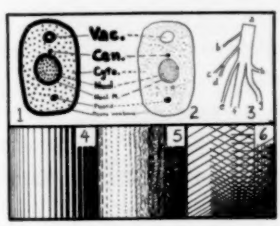

FIGURE 9. Reduced to quarter size; note washing out of stippling, running together of lines, reduction of smaller labelling to a size too small to be read, and effects of reduction on various forms of shading in 4, 5, and 6.

photographs illustrate some of the more important considerations.

Drawings should be made in india ink or other jet black ink on good quality smooth white paper. They may be simple; in fact, the simplest drawings are often the most effective ones. They should ordinarily be drawn at least twice as large as they are to appear in print. The reduction smooths out

irregularities and improves the general appearance. Figures 7 to 9 are printed at only slight reduction from the original size, at half size, and at quarter size, illustrating the effect of reduction on irregularities, contrast, distinctness of lines and stippling, legibility of lettering, and the like. Note that while contrast is reduced in half-tone reproduction of photographs, it may be increased in reproduction of drawings.

Lettering should be large enough so that the smallest letters, such as e and o, are at least a millimeter high in the printed figure. Therefore if the illustration is to be reduced to one half the original size, the smallest letters in the labelling should be at least two millimeters high, and so on for other degrees of reduction.

The following is a suggested check list, by which the writer may determine whether his manuscript is ready to be submitted. The points are not listed in order of importance; their importance may vary in different cases. However, all are significant and should be checked.

1. The manuscript has been read by at least one person qualified to do critical reading.
2. The manuscript has been checked for consistency of form and spelling by someone other than the writer.
3. All quotations have been checked against the original.
4. All literature citations have been checked against the original publications.
5. All tables, calculations, and drafts have been double checked for accuracy.
6. All illustrations have been so arranged as to fit on the printed page.
7. Unnecessary tables and illustrations have been deleted.
8. All technical requirements of typing, illustrations, tables, and references have been met.
9. All illustrations are appropriate to the content of the text material.
10. All necessary and appropriate acknowledgements have been made.
11. All necessary or appropriate approvals by administrative officers have been obtained.

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Biology Students in India

Results of North American biology teaching were displayed in personal and convincing fashion to citizens of India for eight weeks last winter.

Susan Brown of Austin, Texas, and Gary N. A. Botting of Peterborough, Ontario, winners of principal biological honors in the 1960 National Science Fair at Indianapolis, spent eight weeks in India as star attractions and unofficial good-will ambassadors.

The outstanding teenagers, and their exhibits, were taken to India under arrangements made by the AIBS, principally to participate in the Indian Science Congress at Roorkee, January 3-9.

They remained as visiting lecturers touring private schools, institutes, colleges, and laboratories in New Delhi, Calcutta, and Bombay, and returned home February 10.

Their tour was a triumph in every sense. They acquitted themselves beautifully. They impressed Indians of all ages and degrees of education. They unwittingly prompted a famed English biologist now living in India to go on a protest fast, because, through a misunderstanding, they didn't eat dinner with him, and therefore the youngsters received attention in the New York Times.

And above all, they had fun, as only teenagers can. They came home with notebooks lined with names of potential Indian penpals, and souvenirs, gifts, trophies, and acquisitions beyond count. Gary's were the more

Gary Botting, Peterborough, Ontario, winner in last year's National Science Fair, explains a Cynthia moth cocoon to visitors to the Indian Science Congress. He and Susan Brown attended under arrangements made by the AIBS.

dramatic—including a stuffed tiger head, a fearful taxidermic chimera composed by uniting a mongoose attacking a striking cobra, and an Oriental rug—all carried loose since they would not fit in his luggage. Susan's were more lady-like, running heavily to fabrics.

At the Indian Science Congress, the youngsters' exhibits were integral parts of an AIBS display on biological education in the United States. Susan's exhibit depicted her isolation of a root growth factor from pinto bean seedlings. Gary's was a demonstration of his knowledge of *Cynthia* moths, including hybridization experiments.

The official AIBS report on the youngsters' part of the exhibit reads:

"*Winning Biological Exhibits in National Science Fair.* This section proved by all odds to be the most "popular," quantitatively, of the entire exhibit, because of the presence of the two outstanding young people. Students at the University of Roorkee, especially, surrounded the youngsters frequently; at one time when there was no one else in the exhibit room 79 students were counted circling Miss Brown, 7 or 8 deep in concentric rows, while she answered their questions. It is probably that there was some element of other-than-scientific interest involved here; nevertheless the scientific content of the young persons' presentations made an impression, too, on students and senior scientists alike."

Altogether 6,650 visitors saw the youngsters' exhibits at the Congress.

On the rest of their tour, the young people were quartered in India with American families. The United States Information Agency arranged their schedules, provided assistance for them and looked after them.

Susan had been appointed an "American specialist" in the Department of State Cultural Exchange Program, under arrangements completed in her behalf by AIBS. Gary was not eligible for this appointment, because of his Canadian citizenship; he traveled under a grant from the National Academy of Sciences, also obtained by AIBS.

The trip had been arranged by AIBS because of the fine accounting both Susan and Gary had given of themselves at Stillwater, Oklahoma, when they—and their exhibits—were attractions at the Institute-sponsored Annual Meetings of Biological Sciences.

The two so obviously were outstanding, both in personality and as science students, that when the exhibit and delegation to depict American biological education were being assembled for the Indian trip, it seemed only natural to think of including—first their exhibits, and then the youngsters themselves.

U. S. Ambassador Ellsworth Bunker approved the idea and strongly urged that both young people attend. He met them both in New Delhi and again in Calcutta. They also met prominent Indian scientists, teachers, and young people by the score. They saw the filth and squalor of Indian villages and city slums. They saw the gleaming temples of old India and the broad thoroughfares and massive structures of modern India.

And they acquitted themselves well. As they spoke to Indian audiences about their schools, about the National Science Fair, or other aspects of our culture, they were straight-forward, well-informed, and effective.

As they answered the questions of senior scientists or explained their exhibits, or talked about biology in general, they displayed unusual knowledge of their own subject matter

Blonde Susan Brown of Austin, Texas, smilingly explains her winning biological exhibit to a crowd of Indian delegates to the Indian Science Congress, held at the University of Roorkee, India, January 3-9.

and grasp of principles—without being smart-aleck or egotistical.

With American families, with Indian young people at social events or informal meetings, they were relaxed, vivacious, and delightful companions.

Susan, a darling who charmed everyone, instinctively gave the perfect answer even when unexpectedly asked a loaded question about segregation, for instance. Her answer: "It's a problem in some places, but certainly not everywhere. I live in the South, and my school has always been integrated. No one even gives integration a thought where I live." She took along the textbook for her Russian course at the University of Texas and studied it almost every night.

Gary was full of fun, animated, adventurous, and occasionally a bit irresponsible where luggage was concerned. But how he loves to talk about moths! He spent his free evenings writing chapters in a "text-book" on the subject.

In sum, the two were superlative representatives of American-Canadian schools.

Susan is the daughter of Mr. and Mrs. Hiram Brown of 2604 Pecos Street, Austin. Gary is a son of Mrs. Norman A. Botting of 314 Pearl Street, Peterborough, Ontario.

Susan attended the Stephen F. Austin High School. Her 10th grade biology teacher, Mrs. Edna Boon, stimulated her first efforts in special research. A summer biology program of Texas A & M College developed her interest.

Gary attends the Peterborough Collegiate and Vocational School. When he was 6 years old, moths flew in his open bedroom window, and he has collected and studied them ever since.

Book Reviews

BIOLOGY, A BASIC SCIENCE, 2nd. Edition, Elwood D. Heiss and Richard H. Lape, 689 pp., $5.56, D. Van Nostrand Company, Inc., New York, 1961.

A new edition of a text which made its debut in the high school field a few years ago. The illustrations are adequate and not flashily expensive as those in some high school books. The organization of the book is rather traditional in that there is introductory material on science and the cell, followed by an introduction to classification, and going into a comparatively short unit on living processes in plants and animals. It seems that the bulk of the book is on regulation, microorganisms, reproduction, genetics, evolution, ecology, and conservation. A new unit is included on radiation and space biology.

One of the interesting features of the book for this reviewer includes the manner of organization within the chapter. Problems or questions are stated prominently in each chapter, followed by reading material, then some suggested experiments or projects interspersed in the text. The chapter end material includes questions, summaries, projects, and reading suggestions.

There is a liberal use of student names, a practice which the reviewer does not particularly care for. The material seems up-to-date and readable for ninth and tenth grade students. There is a continual emphasis throughout on scientific method.

This *must* be examined for possible adoption by high school biology teachers.

P. K.

PRINCIPLES OF MODERN BIOLOGY, 3rd. Edition, Douglas Marsland, 632 pp., Henry Holt and Company, New York, 1957.

A well known college text and also popular in

high school advanced biology classes. It is well written and easily readable but full of information. The material seems up-to-date throughout. Pictures and especially drawings are unusually good.

It is the organization of the book, however, which raises grave doubts in the mind of the reader of its pedagogical usefulness, however. Biology courses can be organized with introductory material on the cell, chemical basis of life, taxonomy, and then material centered around specific organisms, concluding with genetics, evolution, and ecology. Or, the course can start with the cell, etc., and then go into a discussion of specific life functions with organisms as examples to illustrate the diversity of methods of accomplishing these. This book is of the latter type. Thus, the chapter on digestion includes a discussion on all types of digestion with major emphasis on man. The first unit on the cell is forced to take up the same subject with many organisms used as illustrations. How can a laboratory approach be tied up with this treatment? Meiosis and cell division is taken up in Chapter 3, repeated a little in Chapter 12, and then hauled out again in Chapter 26. This seems to be waste motion. Genetics is removed from the cell by the main part of the book.

Each chapter is excellent in its own right, but the reviewer would be dissatisfied in their arrangement for teaching purposes. There is a final nod to the taxonomic and morphological approach in the final two chapters. Perhaps this book is acceptable for the *second* course in biology.

P. K.

GENERAL BIOLOGY, William Taylor and Richard J. Weber, 945 pp., D. Van Nostrand Company, Inc., Princeton, New Jersey, 1961.

A brand new college text with a traditional treatment. The plant kingdom is treated in unusually full detail. This is followed by the animal kingdom with man and the frog used as type animals for vertebrates. The concluding chapters are on ecology, genetics, and evolution. While there is no chapter-end material, there is an extensive bibliography. The drawings are new, most in three dimensions, and many in color. They are excellent and in detail.

One of the outstanding features is the wealth of detail which is included, especially in the drawings. But another outstanding feature, not often found in college texts, is that there is a traditional approach with the treatment centered around specific organisms in the so-called systematic style. It does not by any means duplicate a high school text, as the detail is too deep, but the organization is similar. It is one of the few texts available for the teacher wanting this approach. A good book.

P. K.

ELEMENTS OF BIOLOGY, Paul B. Weisz, 491 pp., \$6.75, McGraw-Hill Book Company, Inc., New York, 1961.

If the teacher, high school or college, is searching for a new text which has the "new" approach, this book is the prime candidate. In a handsome, square format, the book reads easily with interesting light touches. It is not too long, and the diagrams are new and used as summaries of the complex chemistry and other principles taken up in each chapter.

But what is this new look? It is the highly biochemical slant on biology. Introductory material is on science, the origin of life, the cell, systematics, and ecology. Interestingly enough, protoplasm is next with a discussion of the organization of animals and plants. The author uses some rather uncommonly used taxonomic terms. Metabolism occupies a major section of the book, including elaborate treatments of homeostasis, coordination, etc. Reproduction, genetics, and evolution complete the book. It is apparent that this is not the orthodox arrangement; in fact, it is far to left field.

Besides biochemistry, metabolism, and ultrastructure of cells, the text has a most interesting treatment on the "nature of science." The teacher wanting these approaches emphasized will probably find this the only available text. For those looking for the second course in biology this will probably be a good book to examine, probably the one which will be chosen.

Although the author does not seem to assume much chemistry in the background of his student, it would seem to be necessary for its use. This is the "molecular biology" text. It is important to find out what has been omitted in the "new" look.

P. K.

MANUAL OF BIOLOGY, PART ONE: THE PROTOZOA AND THE PLANTS, 3rd. Edition, Douglas Marsland, 216 pp., Holt, Rinehart and Winston, Inc., New York, 1958.

Presumably written to accompany the general biology text by the same author. However, a totally different approach is assumed here as compared to the text. This is highly taxonomic and morphological. The opening exercises on the cell and how to make drawings are excellent. Teacher aids, such as films, are seriously out of date.

P. K.

LABORATORY MANUAL FOR GENERAL BIOLOGY, 2nd. Edition, Julian P. Cooke, 192 pp., $3.50, Burgess Publishing Company, Minneapolis, Minnesota, 1959.

Meant for a college biology course, the pattern of organization is to have drawing paper and diagrams in last half of book and the instructions in a separate section. The organization starts with the microscope and the cell. The frog and human are used as the chief vertebrate examples. There is a short genetics section. The last half is a fairly orthodox taxonomic approach.

P. K.

LABORATORY AND FIELD STUDIES IN BIOLOGY, A SOURCEBOOK FOR SECONDARY SCHOOLS, Chester A. Lawson and Richard E. Paulson, 281 pp., $1.80, Holt, Rinehart and Winston, Inc., New York, 1960.

This is the published version of the large and valuable document which appeared in 1959 in mimeographed form as a result of a writing conference at Michigan State University under the sponsorship of the National Academy of Sciences. This was preceded by a three-day conference which set up the general format of organization for the writers. The mimeographed edition was quickly exhausted—even at $7.50. The Holt-Rinehart and Winston Company is to be thanked for arranging for this publication.

However, the editors have done extensive editing and rewriting for secondary school pupil use. Although the general organization is largely retained, the studies are revised. Some have been dropped and new ones added.

The original attempts, however, to provide a new rich reservoir of laboratory and field work for the secondary school biology course is retained. Here the teacher will find the ideas for new laboratory work, and plenty of ideas for student projects. There is a complete lack of dissection work, and while some ideas are employed in similar works, there are enough new ones to assure its great value. This book should be on every high school biology bookshelf, but it should be used. The reviewer does not think it can successfully substitute for most teacher's ideas of a lab outline, but it should certainly be used to improve them. Perhaps some college courses could be improved by its use also. A rich book.

P. K.

HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS, Case I, THE SEXUALITY OF PLANTS, 24 pp.; Case II, FROGS AND BATTERIES, 26 pp.; Case IX, THE CELLS OF LIFE, 26 pp., Leo E. Klopfer, Graduate School of Education, Harvard University, Cambridge 38, Massachusetts, 1960.

These are remarkable teaching devices. Each case, titles noted above, consists of a historical development, with quotations from original sources and illustrations of original experimentation, of some basic biological concepts. The margins are liberally annotated with author remarks and questions for students. The opposing page of the text is devoted to thoughtful questions with space for student answers to be written in. There are further reading suggestions, sources used, summaries of the concepts presented, and excellent experiments and project suggestions.

Frogs and Batteries introduces the student to some concepts about the electrical nature of protoplasm through the researches of Galvani, Volta, and Aldini. Hooke, Brown, Schleiden, Schwann, and Virchow are introduced in *Cells of Life*.

The author has done a superlative job using a novel approach to biology teaching. His work in developing the cases is simple, to the point, and full of exciting questions. Biology teachers on all levels will want these. This reviewer is certain that a reading of these will make the teacher anxious for more such case studies in the history of science. This seems the most efficient way of using the historical approach.

P. K.

THE INTELLIGENT MAN'S GUIDE TO SCIENCE, VOL. 1, THE PHYSICAL SCIENCES, VOL. 2, THE BIOLOGICAL SCIENCES, Isaac Asimov, 853 pp., Basic Books, Inc., New York 3, 1960.

These are handsomely done, well illustrated books suitable for the teachers' and students' own library as well as that of the school. The author is skilled, knowledgeable, and writes with an easy style that makes these two volumes books you cannot stop reading. These will be the substantial reference books science teachers will want to fill themselves in on the missing sections of their science background, but they will discover that their up-to-dateness makes them valuable for reading in their own field.

The physical sciences volume is most engaging, beginning with an excellent introduction by George Beadle, and proceeding to descriptions of the latest information worked in with excellent historical background in the universe, earth, atmosphere, elements, particles, waves, machines, and the reactor. Everywhere there is an emphasis on current knowledge but never introduced without detailed background information.

As one reads these two volumes, it appears that simply following Nobel prize winners, their work and its background, might constitute an excellent history of science in this century. This

seems to be the format of the books. But the author's training in biochemistry is readily evident in his treatment of the biological sciences. Here is the case for molecular biology stated well. Morphology, taxonomy, and evolution are lumped together in one chapter while all the other chapters are on chemistry and molecular basis of life. Certainly, the author excels in this area. Descriptions of intricate material are clear and understandable. This is the book to bring biology teachers up to date in the new emphasis in biology. An interesting chapter on mathematics in science concludes the book.

P. K.

THE WELLSPRINGS OF LIFE, Isaac Asimov, 200 pp., \$.50, The New American Library of World Literature, Inc., New York, 1960.

A famed biochemist with a real gift of writing has produced a paperback which could well constitute a good text in elementary biology. The organization of the book should be of real interest to the teacher, but this is not to indicate anything but praise for the wealth of fascinating detail. There is a heavy emphasis on the historical approach to the idea of classification and evolution. Plants are rather conspicuously ignored as the second unit makes a phylogentic survey of the animal kingdom leading to the cell, then chromosomes, and then the gene. This is a very interesting approach as the sequence of topics is classification, evolution, invertebrate survey, chordate anatomy, cell division, chromosomes, and then the gene. It is an easy transition to the molecule and information transfer in genetics. There is a beautiful concluding chapter on the origin of life. An appendix gives a surprisingly detailed listing of dates in the history of biology.

For the teacher interested in the "biochemical approach" a lot of good ideas are found in the book. It has the makings of a good solid text although some areas of biology are conspicuous by their absence.

P. K.

THE DOUBLEDAY PICTORIAL LIBRARY OF NATURE—EARTH, PLANTS, ANIMALS, James Fisher, Sir Julian Huxley, Sir Gerald Barry, and Dr. J. Bronowski, 359 pp., \$9.95, Doubleday & Company, Inc., Garden City, New York, 1961.

This is the second volume of what one author has called "furniture books," that is they look beautiful on furniture. However, this one is far more valuable than that. The first volume took up chemistry, physics, and astronomy, under the heading of "Science." This one covers geology, botany, and zoology, with a heavy emphasis on man.

The illustrations of course are magnificent, but even artistic license does not excuse the erroneous conception given on p. 108. However, the art work and picture selection will draw even the most reluctant child and jaded reader into looking through the book.

Yet it is the content which is important. Since this book is aimed for a general readership, including junior and senior high school students, it is interesting to see what is included and what is omitted. Biology in the ordinary sense, anatomy and physiology, is given little space. Taxonomy is reserved for the appendix. A major section, as one might guess when noting Huxley as an author, is devoted to successive chapters on reproduction, genetics, and evolution. These are excellent. Other major sections, written lucidly and in detail, are on animal behavior, biogeography, ecology, and anthropology. The book is worth the price for just these chapters.

The book is excellent for the audience for which it was intended. However, this is the type of book also for the high school general library. It will be a frequent gift to your students.

P. K.

INTRODUCTORY BOTANY, Arthur J. Cronquist, 892 pp., \$9.25, Harper and Brothers, New York, 1961.

A new text for the elementary college botany course. Handsomely done, pictures that are plentiful and pertinent, and excellent diagrams, this text can also find its place in the high school laboratory. The author follows a fairly orthodox arrangement of chapters with scientific method, cells, mitosis, and taxonomy occupying the first part, and genetics, evolution, and plant geography constituting the finale. An appendix contains a highly detailed key to the plant orders. The middle section of the book is a phylogenetic review of plants, with chapters interspersed on some plant physiology. Pictures of famous botanists are a unique feature. Photosynthesis and other aspects of plant physiology receive short and inadequate treatment. The space spent on bacteria and viruses does not seem pertinent as most botany courses seem to be taught. Genetics also does not seem to get its just due in light of modern trends. But all in all, it is a good text and should be examined for adoption as well as a reference for high school courses.

P. K.

LABORATORY WORKBOOK IN INTRODUCTORY BOTANY, 3rd. Edition, Wendell H. Camp, \$4.00, Burgess Publishing Company, Minneapolis, Minnesota, 1959.

A well written lab manual for the elementary botany course. The artist has used soft lines for the drawings which do not appeal to this reviewer, but detail is not too obscured. A phylogenetic review of the plant knigdom is at the

end of the book, and the emphasis seems to be on life cycles. There is an emphasis on genetics. There are plant physiology experiments. There are blanks to fill. The life cycle of the flowering plant is quite detailed. A manual to examine for adoption.

P. K.

LABORATORY STUDIES IN GENERAL BOTANY, William M. Carlton, $4.50, The Ronald Press Company, New York, 1961.

A new and large lab manual and workbook for elementary botany. The author's experience in teaching the elementary course is easily apparent as the manual is filled with a great deal of information, useful tables and references, and an interesting development of the subject. There are many plant physiology experiments, and these are well done. A survey of the plant kingdom is at the end of the book, but it is handsomely illustrated, especially for the algae, fungi, and liverworts. Of course, there are many other line drawings and photographs—all well done. There are occasional sheets to be completed by the student and handed in. Throughout every effort is made to emphasize experimentation. Certainly plant anatomy is present, but the emphasis is on physiology. There is a short treatment of bacteria. There is a very useful table of references to standard botany texts. It is a pedagogically efficient work. Highly recommended.

P. K.

ATLAS OF PLANT MORPHOLOGY, PORTFOLIO I: PHOTO MICROGRAPHS OF ROOT, STEM AND LEAF, Emma L. Fisk and William F. Millington, 60 pp., $3.00, Burgess Publishing Company, Minneapolis, Minnesota, 1959.

A loose-leaf collection of photomicrographs to supplement plant morphology work. There are no lab directions but a simple collection of excellent photomicrographs of plant tissues. The introductory statement identifies the tissue, species involved, and notes the tissues and structures to be identified. There is marginal space next to each photograph to permit student labeling. The reproduction of photographs is good.

P. K.

LABORATORY GUIDE FOR ELEMENTARY PLANT PHYSIOLOGY, 2nd. Edition, Rufus H. Moore, 146 pp., $3.00, Burgess Publishing Company, Minneapolis, Minnesota, 1960.

While this is written, as the title indicates, for the elementary course, high school biology teachers will find a wealth of experiment ideas for teaching as well as projects. The book presupposes some knowledge of chemistry and consequently is able to offer a great many cell metabolism experiments. An excellent feature is an appendix on greenhouse procedures and often used biological chemicals. Directions are clear and illustrated. Highly recommended.

P. K.

THE LIFE OF THE GREEN PLANT, Arthur W. Galston, 116 pp., Foundations of Modern Biology Series, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1961.

This volume cannot stand by itself because it completely omits a discussion of respiration. By combining this with McElroy's book, a fairly good coverage of plant physiology may be obtained. Galston exhibits an admirable respect for the importance of knowledge of structure when dealing with function, an appreciation which has led him to intrude somewhat on the domains of Swanson (The Cell) and Bold (The Plant Kingdom). He also overlaps other volumes in the series by repeating the "lock and key" interpretation of enzyme substrate association and the "central dogma" of DNA-RNA-protein relations. The biochemical and biophysical aspects of photosynthesis are treated with what appears to be a proper degree of simplification without sacrifice of accuracy.

A few errors have passed by the editors. Figure 15 is reversed and consequently does not agree with the caption. Figure 16 shows the wall of an exceptional cell without indicating in text or legend the departure from the commoner types. In Figure 42, the cambium is omitted from the lower diagram showing secondary thickening but is included in the upper diagram of a root without (*sic*) secondary thickening. There is also some tendency to introduce technical terms, e.g., "endogenous," abruptly and without explanation. This may be disturbing to beginning students.

Plant growth, differentiation, and morphogenesis are presented from the experimental viewpoint with much very modern work included. Botany needs some great integrator, however, who could organize this area into a field as unified as animal embryology has become.

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THE PLANT COMMUNITY, Herbert C. Hanson and Ethan D. Churchill, 218 pp., Reinhold Publishing Corporation, New York, 1961.

This rather brief ecological textbook is divided into four parts: the species and populations, the community, dynamics of communities, and classification of communities. The first part which has too seldom been treated in ecological texts, although fully deserving of discussion in such works, is hardly adequate, perhaps because too much is attempted in too short a space. The im-

portance of hybridization is mentioned, but no distinction is made between hybridization without chromosome doubling and allopolyploidy. Heslop-Harrison's textbook is cited as the reference for ecotypes when it would have been desirable to have cited more original works, Turesson and Clausen et al, in this connection. The role of reproductive isolation could have been included in the discussion of the relationship of individuals of different species. The statement on page 53 that "Nitrogen-fixation bacteria are most commonly associated with legumes, but they are also found with alders and the black locust. . ." is curious, since the black locust (*Robinia pseudoacacia*) is a legume. The numerous photographs mostly furnished by the U.S.D.A. Soil Conservation Service, are for the most part very good, but some are not too pertinent. A bibliography of 213 titles is included.

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Indiana University

THE STUDY OF PLANT COMMUNITIES, Henry J. Oosting, 440 pp., W. H. Freeman and Company, San Francisco, California, 1956.

This text was written for an introductory course in plant ecology. The book is well done insofar as publication is concerned—good binding, size, and format. However, the choice of pictures, while adequate, does not seem to indicate much recency. The chapters take up many interesting aspects of the subject, but the writing is straight forward and not flamboyant or picturesque. All in all, it is a workmanlike job, well done for its intended use.

P. K.

HOW TO KNOW THE FERNS, Frances Theodora Parsons, 215 pp., $1.25, Dover Publications, Inc., New York, 1961.

This is a reprint with some modifications in paperback of the original 1899 edition of this work. The illustration plates are from the original and are well done. The book starts out with a seasonal description of ferns and then some morphological characteristics. The major section of the book is a careful description of species with a key as an introduction. Probably the best fern identification book one can obtain in such a handy package.

P. K.

CORK AND THE CORK TREE, Giles B. Cooke, 121 pp., $7.50, Pergamon Press, New York, 1961.

This little book might be called "All About Cork." The author treats the history, botany, chemistry, uses, and production of cork. The chapters on the many uses of cork are perhaps the most interesting. The final part of the book deals with cork plantings in the United States, and the author concludes that this oak will become of increasing importance as an ornamental shade tree in the southern part of the country.

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COLLEGE ZOOLOGY, Robert W. Hegner and Karl A. Stiles, 726 pp., $7.50, The Macmillan Company, New York, 1959.

There is a new look in an old reliable text, familiar to thousands of students of elementary zoology. Prof. Stiles has made some extensive revisions in this classic, but it still retains its wealth of detail on the animal phyla. The greatest improvement has been in the pictures and superb diagrams. Of course, the chapter on cells and protoplasm received extensive rewriting. The frog is introduced first in the vertebrate treatment, and it contains some references to human analogies. The use of human examples is also present in the mammalian body system descriptions, especially in the nervous, reproductive, and endocrine systems. A chapter on the history of zoology concludes the book, preceded by an excellent chapter on ecology and zoogeography. Otherwise the book retains the phylogenetic review of the animal phyla. What would a biology classroom library be without Hegner?

P. K.

INTEGRATED PRINCIPLES OF ZOOLOGY, 2nd. Edition, Cleveland P. Hickman, 972 pp., $7.75, The C. V. Mosby Company, St. Louis, Missouri, 1961.

This is the revised edition of a popular zoology text for the elementary course. There is the usual introduction on science, cell, etc. The bulk of the book is a review of the phyla with the frog as a vertebrate type animal. The organ systems are then reviewed as related to man. Genetics and evolution are taken up in the next unit. But it is the unit on ecology, zoogeography, adaptations, and animal behavior which the author does up very well. Each chapter has an unusually comprehensive, annotated reading list, and this is complemented by a history of biology and zoology, including the books involved. The drawings use a great deal of shading, and thus some detail is obscured. However, this is an excellent text for college classes, and high school teachers should find it also of value.

P. K.

ELEMENTS OF ZOOLOGY, 2nd. Edition, Tracy I. Storer and Robert L. Usinger, 464 pp., $7.25, McGraw-Hill Book Company, Inc., New York, 1961.

This latest revision of a famous book is edited to make it usable as a text for a short, elementary

course in zoology. Part I takes up general animal biology organized around functions with genetics and evolution concluding it. Part II, about half the book, surveys the animal kingdom in a taxonomic fashion. The conclusion of this section is on man with some anthropology included.

The illustrations are excellent and quite useful for pedagogical purposes. For instance, the cutaway diagrams of animal anatomy embody color to follow body systems. Line drawings are skilfully done. The wealth of detail in the original text which made it useful as a reference is now considerably reduced, and thus the new book becomes more useful as a text. There is still an over-abundance of terms in bold-face, but it reads well. Questions conclude each chapter. The format is attractive.

This is a zoology text that would be well to use in an elementary course, but it is still a useful reference for the general biology course. A well-done book deserving its popularity.

P. K.

ZOOLOGY, 3rd. Edition, A. M. Winchester and Harvey B. Lovell, 645 pp., D. Van Nostrand Company, Inc., Princeton, New Jersey, 1961.

A popular first year zoology text has had a complete revision, but the author's ability to present in a lucid way a solid course is apparent throughout. Although the chapter sequence is rather orthodox, and the author defends it well, the treatment of such things as the introductory chapter on science and scientific method is superb. The chapter on the chemistry of life is also another example. The review of the animal kingdom occupies the major section of the book. Vertebrates are introduced by a description of man and the frog. Genetics and embryology are other examples of the author's skill.

The illustrations, particularly the pictures, are excellent and not the usual ones found in texts. Each chapter ends with student questions. There are no other reading references, but there is a glossary. This will make a good text for the zoology course, but the high school teacher will find it a good reference.

P. K.

LABORATORY GUIDE FOR ZOOLOGY, 3rd. Edition, A. M. Elliott, 229 pp., $3.25, Burgess Publishing Company, Minneapolis, Minnesota, 1957.

When a lab manual reaches a third edition and several printings, its worth is rather well established and solid, and this is the reputation of this manual. It is richly deserved. The line drawings, most of them three-dimensional views, are stunning. A student has some good models. The manual is so constructed that it fits well into each unit of an elementary zoology course, even to an excellent exercise in scientific method. There are simple but interesting and ingenious experiments in metabolism for the beginning student. The review of the animal kingdom contains interesting information about each type animal which is utilized. The frog is the major vertebrate animal used, and, again, the drawings are stunning. The chick and the fetal pig are used for embryology studies, but the fetal pig treatment rivals many lab manuals devoted solely to it. This is the best lab manual in zoology this reviewer has seen.

P. K.

TAXONOMIC KEYS TO THE COMMON ANIMALS OF THE NORTH CENTRAL STATES, Samuel Eddy and A. C. Hodson, 162 pp., $3.25, Burgess Publishing Company, Minneapolis, Minnesota, 1961.

This is a third edition of a fine book and a must for every biology teaching library. The keys to the animals embrace protozoans to mammals. However, there are wonderful line illustrations which will be of great use to the student. Especially are they valuable in identification of the protozoa, rotifers, leeches, clams, snails, microscopic crustacea, Cladocera, copepods, aquatic insects, mites, and fish. Other phyla are not ignored, but these are especially featured, especially protozoa and fish. This is certainly a highly recommended reference for all biology teachers whatever level.

P. K.

INVERTEBRATE ZOOLOGY LABORATORY WORKBOOK, D. Elden Beck and Lee F. Braithwaite, 290 pp., $6.00, Burgess Publishing Company, Minneapolis 15, Minnesota, 1961.

The title is self explanatory, but it does not tell of the wealth of exquisitely done diagrams and drawings, and some dissection photographs. Protozoa are taken up in great detail. Each of the invertebrate phyla are described in detail, and there is a great amount of anatomical detail given for each species. This is almost more than a simple lab manual, as it can easily be used as a text. Of course, it will make a superb manual for the invertebrate course, but it will be a most handy reference book for the high school biology library. It should be on hand in every general biology lab. Highly recommended.

P. K.

CULTURE METHODS FOR INVERTEBRATE ANIMALS, Frank E. Lutz, Paul L. Welch, Paul S. Galtsoff, and James G. Needham, 590 pp., $2.75, Dover Publications, Inc., New York, 1937.

Those who know this book, know it as a classic. Those who do not should purchase it immediately. This is a well done paperback edition published in 1959 of this authoritative work

completed in 1937. A biology lab is not complete without it as a handy reference.

It is a collection of some 300 articles on various invertebrates and their culture by various authorities. An introductory unit includes material on collection of specimens and the maintenance of various types of aquaria. There are illustrations. Teachers looking for projects will find it a gold mine.

For those who believe only molecular biology is now acceptable, they should use this to restore their knowledge of this fascinating field. Molecular biologists must eventually depend on these techniques. A real gem.

P. K.

HOW TO KNOW THE AMERICAN MARINE SHELLS, R. Tucker Abbott, 222 pp., $.75, The New American Library of World Literature, Inc., New York, 1961.

A new paperback which by all means should be on the shelves of biology laboratory book shelves of any school within reach of the ocean, and it seems quite appropriate that it be found in other school libraries as well. It is written in the best tradition of a good natural history book with an excellent introductory chapter on the fascination of studying sea shells. Other chapters are on the anatomy and life history of the molluscs, collecting methods, and even how to organize a shell club. The main portion of the book is a taxonomic treatment, liberally illustrated, including some beautiful color plates. A good buy.

P. K.

INSECT LIFE AND INSECT NATURAL HISTORY, S. W. Frost, 526 pp., $2.25, Dover Publications, Inc., New York, 1959.

This is a paperback edition of a 1942 book with full illustrations. The paper is good, and illustrations are well reproduced. There is also an attractive cover. Although this is a text for entomology courses, there is some taxonomic work included. A key to the principal orders is given, and the appendix carries a key to the immature insects. The title indicates a special and well done feature of the book—insect natural history. There are good chapters on color, sonification, behavior associations, gall insects, etc. The strength of the book is in these fascinating accounts of insect life. High school biology libraries should have reference works on entomology. This is a classic which belongs there.

P. K.

101 SIMPLE EXPERIMENTS WITH INSECTS, H. Kalmus, 194 pp., $2.95, Doubleday and Company, Inc., Garden City, New York, 1960.

This book is a real gold mine for the teacher looking for "project ideas" and demonstrations for the laboratory. All can be done with very little equipment and have a simple rationale which makes them easily adaptable for student use. It is refreshing to note how many things can be done without elaborate equipment. Originally written for a British audience, the book suffers from some expressions and terms which will need some interpretation by the unsophisticated American reader. For instance, there are many references to "stick" insects which are not too easily available here. Two American biologists made many adaptations for this printing, but there still remain "odd" references, such as "Mecanno cogwheel." Instar is another term seldom used in high school biology. All in all, it still remains fertile with good ideas.

P. K.

INSECTS CLOSE UP, Edward S. Ross, 79 pp., $1.50, University of California Press, Berkeley, California, 1953.

A well illustrated paper-back booklet on good quality paper utilizing color quite effectively. Common insects are described with an interesting natural history approach. It is not an identification manual, but there are instructions on insect collecting, surveys, photography, and further references.

P. K.

TEN LITTLE HOUSEMATES, Karl von Frisch, 146 pp., $2.00, Pergamon Press Inc., New York, 1960.

A delightful little book, written in non-technical language and well translated, by the renowned German entomologist. It contains ten common household insects: housefly, gnat, flea, bedbug, louse, clothes moth, cockroach, silverfish, spider, and tick. Well illustrated, the author uses a variety of personal experiences to tell about these common insects. For instance, the story of the engineering ability of the spider and the remarkable sensory abilities of the tick are well told. If this is nature study, so be it. But all biologists will enjoy it and value its fascinating insights. Reads well for high school students.

P. K.

COMMUNICATION AMONG SOCIAL BEES, Martin Lindauer, 143 pp., Harvard University Press, Cambridge, Massachusetts. 1961. $4.75.

As far as this reviewer is concerned, this is one of the most fascinating books to come along for some time. The author is a student of von Frisch and has carried his famous experiments several steps further. The book is the result of some lectures at Harvard on his studies, and it is enhanced by most appropriate pictures and diagrams. It is written in charming style and dis-

plays great modesty but thoroughness of research so that the results easily speak louder than any of the author's disclaiming references to himself.

The discovery of von Frisch of dances as a method of communication among bees has been enlarged by many clever experiments using differing strains of bees, using northern versus southern hemisphere locales, noticing developmental stages, influence of the sun, etc. A most appropriate book for recreational reading even though it is deadly serious. If this is natural history, so be it, but what profound discoveries have been made in its name.

P. K.

HOW TO KNOW THE BUTTERFLIES, Paul R. Ehrlich and Anne H. Ehrlich, 262 pp., Wm. C. Brown Company Publishers, Dubuque, Iowa, 1961.

Another one of the superb "How To Know" series. This latest publication uses the familiar ring binder, but colors are not used although for this particular subject this might have been appropriate. The introductory material is well done with information on morphology, sex, classification, and collecting ideas. Those biology teachers already familiar with this series will want this latest addition. Those who are not should.

P. K.

WESTERN BUTTERFLIES, Arthur C. Smith, 65 pp., $2.95, Lane Book Company, Menlo Park, California, 1961.

Written for junior high and elementary school pupils, this delightful and colorful little book is more than just a classification manual. It tells in a fine style about butterfly habits, morphology, metamorphosis, etc. The insects are introduced by ecological habitat where they are likely to be found. A fine elementary science library edition.

P. K.

FUNCTIONAL ANATOMY—MAMMALIAN AND COMPARATIVE, 3rd. Edition, W. James Leach, 338 pp., $6.50, McGraw-Hill Book Company, Inc., New York, 1961.

While this text superficially may appear to be a traditional text in comparative anatomy, it is much more than that. The cat is the chief dissection specimen used. The illustrations seem adequate but probably could be improved by less use of deep shading.

The introduction is studded with terms and definitions until it appears to be an annotated glossary. There is a good review of the phylogeny of mammals. But the major part is devoted to a functional anatomy of the cat. An appendix gives valuable information on preparation of dissection material. Throughout the author emphasizes the importance of anatomy as the key to understanding function. An interesting treatment and approach.

P. K.

VERTEBRATE BIOLOGY, Robert T. Orr, 400 pp., W. B. Saunders Company, Philadelphia, Pennsylvania, 1961.

This is a most unusual treatment of a familiar subject based on the author's course in this subject. The book starts out with a highly anatomical treatment of fish and then on through amphibians, reptiles, birds, and mammals. The other two-thirds of the book is on systematics, distribution, population movements, reproduction, growth, and population dynamics. The real strength of the book is in this major section. These treatments are well done and highly original, using examples and illustrations not often found in most texts. The publisher has also done an attractive job.

The reviewer found the chapters on population movements, dormancy, and population dynamics of especial interest and probably importance.

This is a good and novel book and probably will be a highly successful text in such courses.

P.K.

MAMMALS OF WISCONSIN, Hartley H. T. Jackson, xii + 504 pp., $12.00, University of Wisconsin Press, Madison, 1961.

Jackson's *Mammals of Wisconsin* contains technical and natural history data on eighty-four kinds of mammals known to occur now, or for which there are reliable historical records in Wisconsin. For each species the accepted scientific name; synonymy; vernacular names; identification data including tooth formula, size, and color of pelts at various seasons; and a list of the specimens examined are given in the text. There is also an extensive discussion of the ecology and natural history in which information is given about populations; nests, trails, and the like; reproductive behavior including mating, parturition, and care of the young; food habits; enemies; and parasites. There are photographs of each animal in its natural habitat and drawings of the skull, feet, tracks, and fecal deposits. There is a map showing the distribution of each species in Wisconsin with a small insert showing the distribution in North America. The text is written in a readable style that should stimulate interest in the study of mammals and their ecology. There is an extensive bibliography and an adequate index.

This work will be useful to biology teachers in Wisconsin and neighboring states. Since most of the species listed are found in much or all of

the northern tier of states and in the southern provinces of Canada, this book should be available to students who spend vacations in these areas.

John M. Hamilton
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Parkville, Missouri

LIVING FISHES OF THE WORLD, Earl S. Herald, 303 pp., $12.50, Doubleday and Company, Inc., Garden City, New York, 1961.

Another one of the The World of Nature Series which is absolutely stunning. It is hard not to use superlatives in writing about this book. The outstanding feature of the book is the illustrations, particularly the remarkable color photos of the species. Photography enthusiasts and even artists will relish this book. But to the biologist the book is of value because of the informative, easy to read style, treatment of the families of fish of the world. There are occasional pages on such things as poisonous fish, electric fish, etc. The author adds to each treatment informal items of personal experiences, reports on the habits of the fish, etc. There is very little on fish anatomy, but a wealth on fish habits, life histories, ecology, and external appearance. This is a must book for the high school library as well as the laboratory, but the college library will want it too. It is hard to see how any icthyologist, amateur or prefessional, will be without it. The publishers have done an excellent job also. Highly recommended.

P.K.

BIRD PORTRAITS IN COLOR, Thomas Sadler Roberts, $5.95, University of Minnesota Press, Minneapolis, 1960.

This handsome book contains stunning color plates of birds, common to Minnesota, but also common in many other areas. Each plate is faced with a description of the species pictured and a great many detailed notes about the species. These are well-written and easily readable as they are not in the usual "note" style. The plates are most important, however, and all ornithologists will enjoy reviewing this. The several printings this book has undergone is witness to this. However, teachers will find this a most appropriate book for bird identification.

P.K.

FETAL PIG MANUAL, C. A. Leone and P. W. Ogilvie, 52 pp., $2.50, Burgess Publishing Company, Minneapolis, Minnesota, 1960.

The fetal pig has become a popular dissection specimen if the number of lab guides now in existence are any criterion. This one employs photographs of the dissection steps. However, the photographs are disappointing in the lack of contrast of organs. Admittedly, it is a difficult one to photograph effectively. The instructions are quite detailed and well done. The circulatory system is emphasized.

P.K.

ADVANCES IN SMALL ANIMAL PRACTICE, Vol. II., Bruce V. Jones, 148 pp., $8.50, Pergamon Press, New York, 1961.

This book presents the papers that were read at the 1960 British Small Animal Veterinary Association Congress. A few papers deal with problems involved in cat practice but the majority are concerned with canine problems. The first symposium is on internal parasites of the dog. Three papers describe the incidence, life cycles, and host-parasites of some canine nematodes and tapeworms. One paper reports treatments for various internal parasites such as ascarids, whipworms, and tapeworms. The second symposium dealt with the problems involved in transporting dogs and cats from one country to another. Surgical demonstrations is the topic of the third symposium. Ten papers describe techniques such as total mastectomy, blood collecting and transfusions, tooth extractions, and methods of anesthesia. Other subjects covered were cardiac disease, glaucoma, and the use of tranquillizers in canine practice. The majority of the papers are well illustrated and are followed by spirited group discussions. Some papers of particular interest to the veterinarian are concerned with dog shows and progress in the profession.

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PRINCIPLES OF ANIMAL TAXONOMY, George Gaylord Simpson, 247 pp., $6.00, Columbia University Press, New York, 1961.

This is an important book and one that has long been needed. Perhaps no branch of biology is as poorly understood or as misunderstood as taxonomy, not only by laymen but by many who call themselves taxonomists. It may seem strange for a botanist to review a book on zoological taxonomy, but as Simpson points out, most of the principles apply equally well to plants. This is not a particularly long book, but it covers the subject most adequately. The reader should be warned that it is not an elementary treatment, but the style is such that it is most readable. Although I feel certain that not all taxonomists will accept all of his conclusions, few modern taxonomists will find much with which to disagree.

If one were to pick a single theme for the book it might well be that "the principles of modern taxonomy are evolutionary." Another

current running throughout the book is that while taxonomy is a science, its practice involves art as well as science. In the space of a brief review it is difficult to know which of the many topics covered should be discussed, but some indication of the overall content will be given as well as comments on certain selected topics which are of particular interest to this reviewer.

The first chapter on "Systematics, Taxonomy, Classification, Nomenclature" discusses these and more subjects. We learn that taxonomy is "most explicitly and exclusively devoted to the ordering of complex data," and as such, it has both an "aesthetic" and "almost a superscientific place among the sciences." He then defines the terms he is going to deal with, a feature of this and other chapters which is of great help to the reader. The definition of systematics and taxonomy is of particular interest because these terms have been defined in several ways in the past, and a great many biologists at present treat them as synonymous. Simpson, however, defines systematics as "the scientific study of kinds and diversity of organisms and of any and all relationships among them," whereas "taxonomy is the theoretical study of classification, including its bases, principles, procedures, and rules." This latter definition is somewhat more restricted than previous ones, and he points out that he himself has used the word taxonomy somewhat differently in earlier works. He does not go into a detailed history of the term, taxonomy, but points out it dates from 1790 according to the Oxford English dictionary. Herbert L. Mason (Madroño 10:193-208. 1950) credits the term to A. P. de Candolle in his "Theorie Elementaire" of 1813, in which he defines it not too differently from Simpson. Neither de Candolle's work nor Turrill's important contribution, cited by Mason, were apparently seen by Simpson. Although this is not offered as a criticism of Simpson's work since his book is intended solely to cover zoological works, it is important to note, however, that botanists have also contributed to taxonomic principles and that some attention to their works could have resulted in an even better and more useful book.

In his first chapter, Simpson, among other things, also discusses and disposes of set theory and symbolic theory in biological classification. His discussion of types and the type concepts, actually a relatively simple subject but very often misunderstood, is most worthwhile. His suggestion that only four types (holotype, syntype, lectotype and neotype) are needed for taxonomy is applauded by this reviewer, since the number of types in use by some taxonomists has reached a ridiculous extreme.

Chapter Two deals with "The Development of Modern Taxonomy" and again much more. A brief historical survey with a particularly valuable discussion of typology is included. In his discussion of the discovery of phylogeny, he points out that Lamarck was the first to consistently maintain that all taxa arose by evolution, and in a footnote he makes the interesting observation that this is the "most original and one still acceptable principle of Lamarckism. Lamarck would be astonished to know that 'Lamarckism' has come to mean the inheritance of acquired characters." The chapter ends with a discussion of the new systematics, and though well known to most modern taxonomists, his statement that "populations, not individuals, are the units of systematics and are the things classified" is worth repeating. His final sentence of the chapter points out that while formal classification is a part of taxonomic work, "the aim of taxonomy is to understand the groupings and relationships of organisms in biological terms."

The next chapter, "Taxonomic Evidence and Evolutionary Interpretation" begins by pointing out that the data used by taxonomists "include practically everything that can be learned about an animal." In this connection he points out that detailed genetical analysis has had limited application in animal taxonomy for obvious reasons, and it might be mentioned that it is in this area that the botanist has assembled far more data than the zoologist. A rather lengthy discussion follows on one of the very basic problems of taxonomy, how to distinguish among the various kinds of similarities–homology, homoplasm, parallelism, convergence, analogy, and mimicry–all of which are defined and discussed. He points out in particular the difficulty of distinguishing parallelism from homology and convergence, and concludes that parallelism cannot in the final analysis always be distinguished from homology. A discussion of criteria for determining primitive characters is also presented.

In Chapter Four we go "From Taxonomy to Classification," and the art versus science aspect of taxonomy is again discussed. Simpson admits that some procedures in classification must be arbitrary, and says that, "nomenclature is an art and not a science at all." The statement is made and, of course, it is no novel idea, that the results of the taxonomists' "art" should be useful, and the most useful classification is the most stable. This, of course, poses a paradox since classification must change as our knowledge about organisms increases. The idea that no classification yet devised can fully express phylogeny comes in for some attention and he points out that Darwin was well aware of the difficulties of expressing phylogeny in classification. Among other topics included in this chapter are monophyly and polyphyly (the reticulate pattern in plants resulting from polyploidy, of course, are

not shared by the animal kingdom and so receive no discussion), vertical vs. horizontal classification, divergence and diversity, and splitting and lumping.

The species and lower categories are the subject of the fifth chapter. He points out that the "species problem" has probably caused more ink to flow than any other one topic in taxonomy, and it might be added that the end is not yet in sight. His discussion of the problem is most sensible, and while not necessarily disagreeing with the genetical definition of species, he feels that it is better to have a somewhat broader one —"An evolutionary species is a lineage (an ancestral-descendant sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies." He admits that there will be doubtful cases as to whether an organism has yet attained the species level. He then discusses uniparental (asexual) organisms and comes to the conclusion that while they differ markedly from biparental organisms, a species definition for them is still possible. The special problem of species in fossils is dealt with in some detail, and this is followed by a discussion of subspecies and other categories. The category, variety, he feels should be done away with entirely. Many botanists are still clinging to the use of the variety, but it is of interest to note that its use in plant taxonomy also appears to be dying out gradually.

The last chapter deals with higher categories. With the great emphasis placed upon species by most modern taxonomists his statement that the genus is frequently "a more usable and reliable unit for classification than the species" is refreshing. He also analyzes some phylogenetic pattern using mammals for his examples, and concludes with a discussion of the evolutionary basis of taxa. His final paragraph, which rather well describes what the book is about, is worth quoting in full.

"It is with the results of all these processes—(adaptation, parallelism, convergence, etc.)—and more!—that taxonomy must deal. The interplay of the processes is so complex that it produces a bewildering array of phylogenetic patterns among all animals, of associations of contiguity and of similarity. Evolution has not provided a series of nicely nested boxes into which all its products fit. Any taxonomic approach that presupposes a simple, natural arrangement that can be found out by either strictly a priori or strictly empirical means is doomed to failure by the nature of the materials to be classified. Yet evolution has not produced chaos or a hopeless tangle, either. It is a completely orderly process, but ordered by numerous interacting, balancing, at times even conflicting principles. The principles can be learned, if only by successive and sometimes groping approximations. There is a science of taxonomy, which adapts the principles of evolution to its special field and adds principles of its own. The principles of taxonomy are applied in classification, which is also an art with canons of taste, of moderation, and of usefulness."

Needless to say, although the book does not take care of all of the problems of the plant taxonomist, this reviewer feels that he can recommend it to the botanist as well as to the zoologist. In fact, any student of evolution, whether or not he is interested in taxonomy, will find this a most stimulating book. And finally it should be pointed out, if it is not already evident, that Simpson has contributed a great service by putting his principles of taxonomy on record.

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ANIMAL HUSBANDRY HERESIES, Allan Fraser, 200 pp. $6.00, Philosophical Library, New York, 1961.

Fraser is a Lecturer in Animal and Dairy Husbandry at the University of Aberdeen. His argument is developed around his statement (p. 63), ". . . the breeding of farm animals for husbandry purposes proceeded wonderfully well without the science of genetics and indeed, without the aid or interference of any kind of science, for very many hundreds of years." He questions the accuracy of livestock pedigrees and the value of livestock shows and other practices of livestock breeders. The chief value, if any, of this book to a biologist is as an example of a supporter of Lysenko's theories outside of the U.S.S.R.

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PARASITOLOGY: THE BIOLOGY OF ANIMAL PARASITES, Elmer R. and Glenn A. Noble, 767 pp., $11.00, Lea and Febiger, Philadelphia, Pennsylvania, 1961.

This textbook differs from most other books in the field of parasitology in that it is primarily concerned with biology of the parasites rather than with the clinical aspects of the infection. Well-chosen examples have been taken from those groups having members which are parasitic on other animals and, to a much lesser extent, those which are plant parasites. Thus, it is possible to find information regarding nematodes infesting plants or parasitic copepods of fish as well as those parasites which utilize man as a host. Several chapters of the book are devoted to such subjects as physiology and biochemistry, ecology, the inter-effects between the host and parasite, and evolution.

The book is extremely well illustrated, the authors having borrowed from many excellent and authoritative sources. The reviewer is somewhat disappointed that the authors did not provide a means, such as keys, for the identification of parasites, at least to the order or suborder level.

Although the book is written primarily for the advanced undergraduate student, high school students with a course in biology should be able to understand much of the material. It can definitely be recommended as a reference book for the high school biology teacher.

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INTRODUCTION TO PARASITOLOGY, Asa C. Chandler and Clark P. Read, 822 pp., $9.75, John Wiley & Sons, Inc., New York, 1961.

This is the tenth edition of a classic text of the field. The latest version gives ample evidence as to why the book has a deserved popularity. There is a splendid introduction which describes the intense interest in this field during World War II and its subsequent decline. The reasons for parasitology's importance is dramatically shown. The chapters on parasitism in general, including a history of the science, are exceptionally well done. Bacteria, rickettsia, viruses, and spirochetes are omitted, but parasites of animals are introduced, especially the zoonose group. Each chapter has full references. Each parasite is described well including the treatment indicated. There are not many pictures, but there are excellent diagrams. The high school biology library should have a reference on parasitology. This is a good candidate.

P.K.

MICROBIOLOGY, Philip L. Carpenter, 432 pp., W. B. Saunders Company, Philadelphia, Pennsylvania, 1961.

It is hard for a bacteriologist to *really* switch to microbiology and give the entire field its just due in an elementary book, but this author's attempt is one of the most successful. About twice as much space is devoted to bacteriology as such as that devoted to protozoa, algae, fungi, rickettsiae, and viruses, but at least *some* space is devoted to other microorganisms. The conscientiousness of the author along this line is further displayed in his treatments of instrumentation for microbiologists, and agriculture, medical, public health, etc., aspects.

The illustrations are excellent and utilize a great number of ultra-microscopic pictures. Each chapter concludes with questions and some annotated reading suggestions. The publisher has done a tasteful job, but the reviewer caught one misplaced chapter heading. It is written as a teaching text, and the author is to be congratulated on the careful selection of sequence and development.

Although the text presupposes chemistry as microbiology is now largely physiological, the high school teacher will find this a very good text to have available. Of course, it is excellent for the elementary course for which it was written.

P.K.

BASIC CONCEPTS AND EXPERIMENTS IN MICROBIOLOGY, Delbert E. Schoenhard, 239 pp., $5.50, Burgess Publishing Company, Minneapolis, Minnesota, 1961.

Designed for the elementary course in microbiology, the chief emphasis is on bacteriology, but some attention is given the algae, protozoa, and fungi. There is a superlative glossary, identification chart, formulae lists, and reading references. The manual goes from microscopy, macro and micro morphology of bacteria (too often emphasized too heavily in high school courses), nutrition, enzymes, metabolism, antibiosis, etc. There are even exercises in genetic recombination. Then there are exercises emphasizing applied microbiology, such as industrial, agricultural, medical, public health, etc., bacteriology. These are exercises easily adaptable for high school class or project use. This manual is practical and eminently suited for a high level college course, but the high school teacher will find it a real treasure trove. Highly recommended.

P.K.

WITTON'S MICROBIOLOGY, Genevieve Gray Young, 586 pp., $8.80, McGraw-Hill Book Company, Inc., New York, 1961.

This is a well used text in its latest edition aimed for those interested in the health sciences, especially for those in nursing. It is a real microbiology book in that it is not devoted exclusively to bacteriology.

The organization relies heavily on a taxonomic approach and microorganisms in relation to food and health. Bacteriological structure, genetics, and microtechniques are taken up first. The bulk of the book is on control measures, infection modes and immunity, pathogens (bacteria, viruses, etc.). An extensive appendix gives an abbreviated classification and bibliography.

While this book is obviously an important one for courses for health science students, it would be a valuable one for high school labs as a reference book.

P.K.

INTRODUCTION TO SOIL MICROBIOLOGY, Martin Alexander, 472 pp., $9.50, John Wiley and Sons, Inc., New York, 1961.

The first unit of this book mirrors its devotion to microbiology by reviewing soil organisms from bacteria to viruses, including protozoa, fungi, and algae. However, the main emphasis is on bacteria. The unit arrangement and informative: microbial ecology, carbon cycle, nitrogen cycle, mineral transformations, and ecological interrelationships. There is a substantial bibliography for each chapter utilizing many original sources. The illustrations are quite good, using many new photographs and line drawings.

The text reads well but is clearly for an advanced student. This permits the author to give unusually thorough and detailed descriptions of the cycles. Tables are used to good advantage to illustrate important ideas. Chemistry background is assumed, but reference to it is made clearly and understandably.

Of course, this will probably be the important text for courses in this subject, but biology teachers, interested especially in agriculture or microbiology, will want this as a reference. A substantial work.

P.K.

QUANTITATIVE BACTERIAL PHYSIOLOGY LABORATORY EXPERIMENTS, Michael J. Pelczar, Jr., P. Arne Hanse, and Walter A. Konetzka, 150 pp., $3.00, Burgess Publishing Company, Minneapolis, Minnesota, 1955.

This is written for the advanced bacteriology class, and as such presupposes a substantial amount of chemistry and some mathematics. While it has enjoyed a great success for classes of this type, high school teachers must view this as an excellent source of lab work and especially projects only if prepared to cope with the bacteriology training it presupposes. There are clearly written and good exercises, using a variety of advanced instrumentation, such as colorimetry, chromatography, spectrophotometry, Warburg apparatus, stains, etc. Of course, this manual or something similar will be essential for those teachers emphasizing a highly physiological approach to biology. There are many techniques to be learned from it. The drawings leave a lot of straight lines to be desired and some checking for labeling, including spelling! But in all, it serves its purposes well.

P.K.

VIRUSES AND THE NATURE OF LIFE, Wendell M. Stanley and Evans G. Valens, 224 pp., $4.95, E. P. Dutton & Co., Inc., New York, 1961.

It is not often that the research staff of a distinguished research center joins together to write a book in a popular style concerning their work. Yet that is what has happened with a Nobel prize winner and the well known Berkeley staff of virologists. The book is the result, initially, of a series of television programs in California on virology. However, the authors have gone further, included some stunning photographs, and used the services of such people as Robley Williams, Frankel-Conrat, Knight, Pardee, Rubin, and Stent.

The book will probably become the popular text on modern virology. Other popular versions of this subject do not include the fascinating detail of lab work which this one carries. The reader is spared a great many details of cell structure and other items of the fundamental biological nature. The authors plunge right into the subject, use simple language, illustrate their points liberally, and explain quite lucidly the intricate details of viral duplication, molecular structure, DNA, and many other fascinating experiments now current.

The other part of the title, "The Nature of Life," is also significant since virology inevitably must consider the nature of its study in relation to life. Some interesting points are made, but the most significant is the implied prediction at the end of the book on the artificial synthesis of life.

A most exciting book for college and high school biology and general libraries. Highly recommended.

P. K.

DNA MODEL KIT, Van R. Potter, $1.00, Burgess Publishing Company, Minneapolis, Minnesota, 1959.

It is a rare biological research laboratory which doesn't have this paper cut-out model of the DNA molecule somewhere within handy reach and inspection. This is based on the famous Watson-Crick hypothesis. It presents in a clever three-dimensional way this famous molecule. The printing on the famous helix is important and makes it also a real teaching aid. The research scientist already knows about this famous model, but it does have a real teaching potential. Highly recommended for the biology teaching lab, high school or college.

P. K.

NUCLEIC ACID OUTLINES, Volume I, Van R. Potter, 292 pp., $5.00, Burgess Publishing Company, Minneapolis 15, Minnesota, 1960.

It is indeed a pleasure to review a book that one can recommend as unreservedly as this one. It is rare indeed that one finds a book in which a semi-philosophical, or, at least, secular viewpoint is combined with a

thoroughly up-to-date treatment. And furthermore, although the book is authoritative, each aspect of the nucleic acids which is considered is dealt with from historical and simple beginnings. Dr. Potter has selected key references which put one in touch with the original, fundamental work and then has built up rapidly to a thorough coverage of current literature. He disclaims completeness in his preface, and certainly the book does not pretend to be a compendium of the vast nucleic acid literature, yet no important development is left undiscussed, and the exceptional and unexplained is at least alluded to with care. The first four chapters of the book provide an excellent review of our present knowledge of the importance and detailed structure of the nucleic acids.

Anyone who wishes to understand modern biology, or at least the biophysical and molecular biological approaches, will find here the essential information which he must have. The remainder of the book is largely biochemical and will require background, but knowledge of the essential material in the first part should be a virtual requirement for students of modern biology. A high school student or a college student lacking organic chemistry will find it difficult going, but the reviewer believes that even such students will find enough understandable to make the book of great value. Parenthetically, it might be noted that the simple DNA model, described on pp. 69-86, is inexpensive and almost indispensable to students at any level.

A final note is that the book is, considering the excellence and the wealth of annotation, extremely cheap by present-day standards. It contains over 500 key references and almost innumerable tables, detailed structures, and pathways which represent a great deal of work of correlation and interpretation all too rare in even authoritative treatises. One must look forward with much anticipation to the second volume which promises to be even more interesting. It is to be regretted that every student of biology cannot take Professor Potter's course, but the two volumes are clearly the next best substitute.

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HUMAN PHYSIOLOGY, Thomas F. Morrison, Frederick D. Cornett, and J. Edward Tether, 408 pp., $5.40, Holt, Rinehart and Winston, Inc., New York, 1959.

Aimed for high school physiology classes, this book is handsome and well illustrated. This is a comparatively new field for text authors, so it is interesting to see what has been done with the problem.

Although the book assumes a high school biology course in the background of the student, there is a great deal of repetition of basic biology which the student should have had. This is especially true in the physics and chemistry and the cell treatments. If the biology course included any human biology there is an additional repetition of material. Presumably, however, there must be *some* review of this basic biology.

There is a general use throughout all the orthodox treatments of the body systems a greater number of terms, some of them not usually found in elementary physiology texts. Completely mystifying to this reviewer is the complete absence of any mention of the reproductive system. The genetics unit has little on human genetics. The chapter end activities are rather pedestrian and miss some good opportunities for student project suggestions.

However, the book does fill a real need in the text field and one cannot quarrel that the text is straightforward and written competently. The authors and publishers are to be congratulated.

P. K.

THE HUMAN ORGANISM, 2nd Edition, Russell Myles De Coursey, 661 pp., McGraw-Hill Book Company, Inc., New York, 1961.

This is a well-known text for elementary human anatomy and physiology courses. The author presents a good case for such a course on the undergraduate level for all students, and his book indicates that it would be excellent for such a course.

The publishers have done an attractive job with the book, each chapter faced with a full page photograph of something pertinent to the chapter. This edition features a long treatment on basic chemistry and physics which leads into cell metabolism. The rest of the organization is fairly orthodox, although excellently written and illustrated.

This would make a very useful text for an elementary course on the human.

P. K.

ELEMENTARY HUMAN PHYSIOLOGY, Terence A. Rogers, 417 pp., $6.50, John Wiley & Sons, Inc., New York, 1961.

A new text for the elementary physiology course. Illustrations are few, well done, and to

the point. The publishers are to be congratulated for a pleasing format and a text that is not formidable in weight and length. Homeostasis is the main theme of the book, and the author writes about it in relation to man in a lucid, concise, yet readable manner. Anatomy is interspersed throughout, but it is held to a minimum. Cells, protoplasm, and elementary chemistry comprise the beginning of the book. The body systems are taken up in their physiological perspective. All in all, this probably will be the popular physiology text. Recommended readings are excellent and rely on *Scientific American* a great deal. Because overburdening detail is held to a minimum, this is a real teaching text.

P. K.

STARLING'S HUMAN PHYSIOLOGY, Sir Charles Lovatt Evans, 1233 pp., Lea & Febiger, Philadelphia, Pennsylvania, 1956.

An old classic in its latest edition. The length will give some clue to its encylopediac nature. Every effort has been made to keep the treatment up-to-date, including fine ultrastructure photographs, reference to modern instrumentation, and recent biochemical references. Heavy emphasis is on the biochemical background of physiological material. After a detailed introduction on biophysical and biochemical principles, there are elaborate treatments of muscles, nerves, blood, circulation, nutrition, excretion, and endocrines. There is a very short reference to genetics. Obviously a real reference book, especially on the college level, since there is a heavy chemical background assumed. High school science libraries may wish this, but it can be used primarily for those with detailed science background.

P. K.

TEXTBOOK OF PHYSIOLOGY, W. W. Tuttle and Byron A. Schottelius, 547 pp., $7.00, The C. V. Mosby Company, St. Louis, Missouri, 1961.

This is the fourteenth edition of the famous text by Zoethout. The new authors have brought the text up-to-date in many ways, but especially in the fields of muscle and nerve physiology. It is truly a human physiology text in that anatomy is brought in only as it pertains to important physiological principles. There is no material on genetics, but this seems quite plausible. The physiology of protoplasm is not taken up in any detail as a descrete topic. However, the material on nerves and muscles is detailed and modern. Blood constituents are well treated. The features of metabolism are taken up in fascinating detail. Although there are not many pictures, diagrams, graphs, and tables are abundant and well done. Every high school biology library should have at least one good physiology text. This is a good one. Certainly it should be studied also for adoption in physiology courses.

P. K.

PHYSIOLOGY OF WORK AND PLAY, Sarah R. Riedman, 584 pp., Holt-Dryden, Henry Holt and Company, Inc., New York, 1956.

While written primarily for physical education students in courses concerning muscular physiology, this book is of value to biologists. A great deal of space is devoted to a review of anatomy and physiology of muscles which should be in the background of such students, however. There are good chapters on muscular anatomy, including ultrastructure material. The chemistry of muscular contraction is also taken up in great detail. Other interesting topics are fatigue, nervous control, effects of muscular activity on other processes, such as respiration and circulation, and its relation to blood. The chapter on effects of odd environmental conditions on muscular activity, such as low pressures, is seriously out of date. The book concludes with a treatment on physical fitness.

A spot check disclosed no reference cited with a date past 1948. This is a serious deficiency in the book, and it is hoped that revision plans are underway.

P. K.